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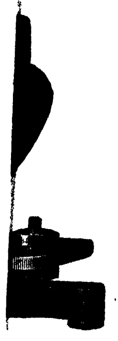

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METEOROLOGICAL OFFICE

THE WEATHER MAP

AN INTRODUCTION TO MODERN METEOROLOGY

THIRD EDITION

Published by the Authority of the Meteorological Committee

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PREFACE

The first issue of "The Weather Map" appeared in the year 1915 in response to a demand for knowledge of the construction and use of weather maps which arose during the war. The rapid sale of this first issue indicated the substantial nature of the demand and in the following 10 years frequent reprints were needed, the sixth issue appearing in 1925. In these reprints certain additions were made but the original text remained practically unaltered. In the intervening years synoptic meteorology had made great strides so that when the sixth issue became exhausted it was felt that the time had come for the book to be rewritten. This was done in 1930 by Mr. J. S. Dines, Superintendent of the Forecast Division of the Meteorological Office, who gave an account of the preparation and use of weather maps which is in harmony with modern British practice.

The definitions of cloud forms given on pages 34–5 of the fourth issue of the second edition were altered from the previous issues to agree with the definitions and descriptions of cloud forms given in the "International Atlas of Clouds and of States of the Sky," issued by the International Meteorological Committee in 1932.

In this the third edition the charts have been brought into accordance with modern practice and some other minor changes have been made.

NOTICE

This book was last rewritten in 1939 before the outbreak of the 1939-45 war. All references to "the war" therefore refer to the war of 1914–8.

Six of the maps given in this edition of "The Weather Map" have been reproduced in pamphlet form, in the hope that the collection will be useful in schools where elementary meteorology is studied and where "The Weather Map" is used as a text-book for this purpose.

Copies of the pamphlet, which is entitled "Examples of Weather Maps" M.O. 337, can be obtained from any of the branches of H.M. Stationery Office or through a bookseller. Single copies, price 6*d*., post free 7*d*.; one dozen copies, 6*s*. 2*d*. post free.

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THE WEATHER MAP

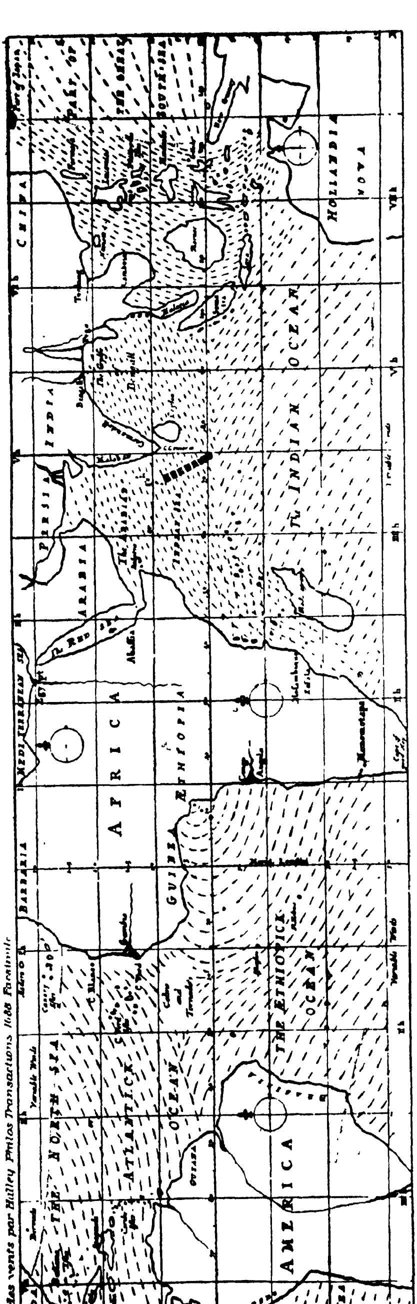
CHAPTER I

Historical

The Oxford Dictionary defines a map as " a representation of the earth's surface or part of it, its physical and political features, etc., or of the heavens delineated on a flat surface of paper or other material, each point in the drawing corresponding to a geographical or celestial position according to a definite scale or projection." A weather map is thus a delineation of the weather over a portion or the whole of the earth on " a flat surface of paper or other material." The term " weather " has a somewhat special, as well as a general meaning. It is frequently employed by meteorologists in a special sense to denote the state of the sky and whether there is precipitation in the form of rain, snow, etc., or absence of precipitation. In its more general sense it refers to all the meteorological factors which affect human beings. Thus while we talk about fine weather and rainy weather we also talk about cold weather, damp weather, stormy weather and foggy weather, using the term in connexion with temperature, humidity, wind and visibility. In its broad sense the term may therefore be considered to refer to the state of the sky, the occurrence or absence of precipitation, the temperature and humidity of the air, the wind and the visibility. There is one further element, which is not covered by the general use of the term but which is of such fundamental importance in meteorology that reference to it cannot be omitted, and that is barometric pressure or the pressure exerted by the earth's atmosphere which is recorded by the barometers and barographs that are found not only in the observatories of meteorologists but also in the houses of private citizens throughout the country. By reason of its importance to meteorology, barometric pressure finds a place on most weather maps alongside the more commonly understood elements of weather.

A weather map is then a delineation of some or all of the following elements over a portion or the whole of the earth's surface ; barometric pressure, wind, state of the sky, precipitation, temperature, humidity and visibility. The map may either give a representation of these elements at any given instant of time, as in the daily weather maps which are now prepared in nearly all civilised countries, or it may show the average weather conditions over a period such as a month or a year. Again the area covered may be as small as a single English county or it may extend to the whole surface of the earth. It will be of interest to trace the development of weather maps, directing attention principally to those made in the British Isles.

It is impossible to say when the first primitive weather map was drawn or by whom it was drawn. In the earliest stage of his existence upon the earth when man had no means of transport but that provided by his own legs, his movements from place to place must have been few and the fact that the weather was different in different districts would be a fact which, if it occurred to him, would have appeared of little interest. He would have had no more use for a weather map than for any other kind of map. Gradually, however, man became more mobile and with the advent of means of travel, particularly of boats, to take him across the sea, it would be forced upon his attention that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MEDITERRANEAN SEA
BARBARIA
FLORIDA
GUINEA
ETHIOPIA

FIG. 1

weather differed greatly between one place and another, and he would begin to realize that if he could obtain some indication of the weather over the sea which he was proposing to traverse, it would be an invaluable aid to him in his journeyings. It is possible that the early seafarers in the Mediterranean and on the North Sea may have followed out this line of argument and constructed some kind of primitive weather map based on the general weather conditions in the districts traversed, as reported by their pioneer compatriots, but if so, we have no record of it and we have to pass on to the end of the 17th century before we find a weather map of which copies have been preserved.

In 1688 Edmund Halley published an account of the trade winds and monsoons, with an excellent map which covered the equatorial regions of the earth from about 30°N. lat. to 30° S. lat. This map is reproduced in Fig. 1 as the earliest known weather map. It must have been based, not on organised meteorological observations, but on the reports of prevailing winds which had been brought back by seafarers and was doubtless of great assistance to the voyagers of those days in planning their journeys over the surface of the oceans. It will be noticed that this map is of the kind which delineates the main features of one meteorological element, the wind, over a period of time. It would have been impossible at that date and for many years after to construct a weather map of the other kind which shows the features of the weather at an instant of time, owing to the lack of any organised system of synchronised meteorological observations. We have to pass on to the early years of the 19th century to find the first attempts at the provision of such a system. When Sir William Herschel, the great astronomer, was at the Cape from 1833–1838 he suggested a scheme for taking meteorological observations simultaneously at different places. He must have had the construction of a weather map in his mind though there is no record of the scheme having been carried to a successful conclusion.

Though a daily weather map can be constructed from observations taken over a wide area and collected in one spot by post or even by slower means of communication, such a map has not much interest unless it can be drawn with so little delay that it represents current and not past weather to those who study it. It was not until the days of the electric telegraph that the quick preparation of a map became possible and in the year 1849 efforts in this direction were undertaken almost simultaneously in America by Professor Henry, Secretary of the Smithsonian Institution, and in this country by James Glaisher, F.R.S., a member of the staff of the Royal Observatory, Greenwich, in association with the proprietors of the *Daily News*, the Electric Telegraph Company and one of the railway companies. Reports from an organised system of observing stations were collected daily in London and published in the *Daily News* for the first time in the issue for August 31, 1848. They were continued until the end of October 1848. The arrangements were reorganised during the next spring, and publication of the reports begun again on June 14, 1849. It does not appear that the publication of a map was attempted but manuscript maps were prepared by Mr. Glaisher, and two years later during the Great Exhibition of 1851 the observations were set out on a map which was manifolded by lithography and sold at the Exhibition for the sum of one penny per copy. An example of this first British daily weather map and the forerunner of the *Daily Weather Report* is given in Fig. 2. The issue began on August 8, 1851, and continued until October 11, 1851, Sundays excepted.*

There was at this time no official meteorological service in England and at the close of the Exhibition the enterprise came to an end. The matter was not, however, allowed to rest for very long. In 1859 it was brought

* *Quart. J. R. met. Soc., London,* **29**, 1903, p. 123 and **30**, 1904, p. 1 and *Symons's met. Mag., London,* **31**, 1896, p. 113.

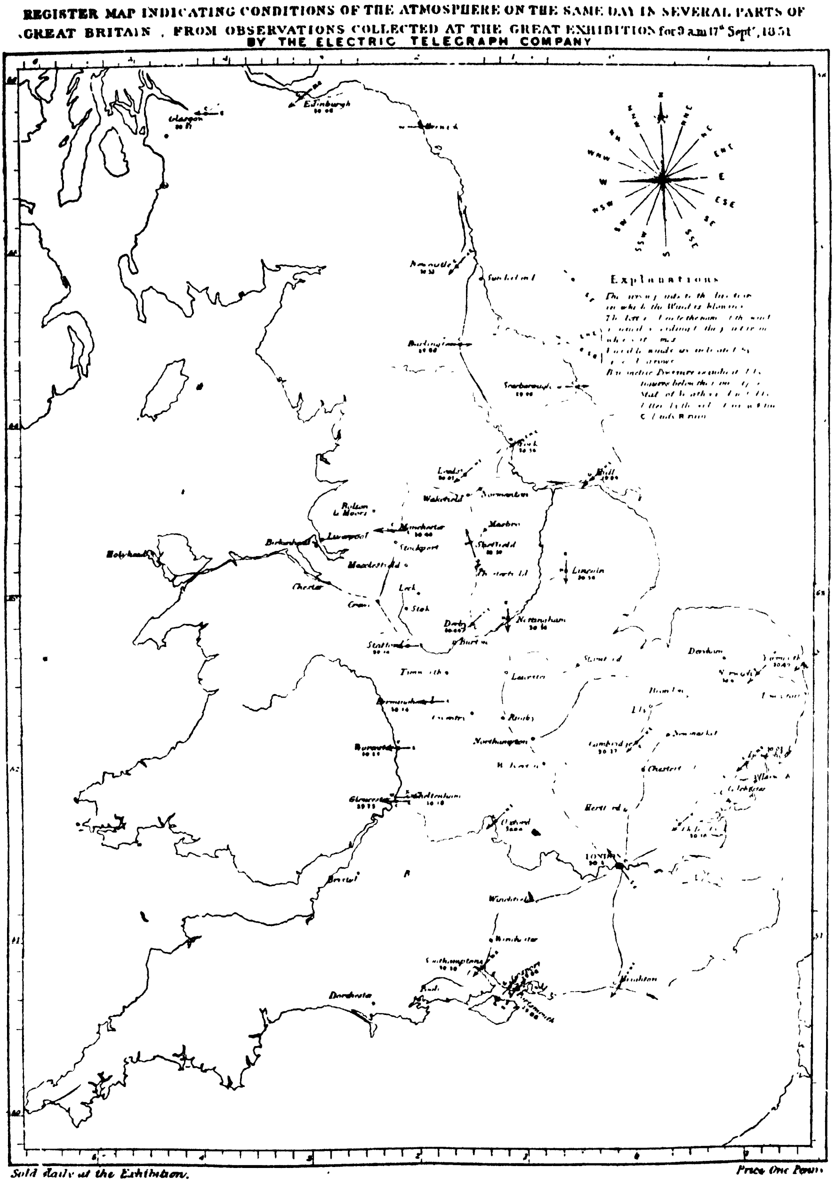

FIG. 2

prominently before the British Association for the Advancement of Science at the meeting held that year in Aberdeen under the Presidency of the Prince Consort. In the intervening years the Meteorological Office had been formed as a department of the Board of Trade under Admiral Fitzroy, and Fitzroy was asked to work out a scheme for collecting meteorological reports by telegraphy and for the issue of occasional warnings of severe gales based

upon them. Almost at the same time the celebrated French astronomer, Le Verrier, who had made a close investigation of a great gale which in November 1854 swept from the south of France to the Black Sea, causing much damage to the Allied fleets there assembled, had convinced the French Government of the usefulness of telegraphy as applied to meteorology and had been entrusted by that Government with the organisation of a system for collecting daily weather reports in Paris. Le Verrier soon realised that reports from his own country would not alone be sufficient to construct a useful weather map and wrote to Sir George Airy, the Astronomer Royal, asking for his assistance in obtaining reports from Great Britain. This request was passed to Admiral Fitzroy and, reinforcing as it did the previous recommendation of the British Association, led to the establishment of a daily weather reporting service in the British Isles and to the issue of gale warnings to ships in the year 1860.

The first British *Daily Weather Report* to be issued by the Meteorological Office appeared on September 3 of that year. It did not contain a weather map and little is known of the method used for charting the data at that time. The observations were set out on an outline map with movable markers which were cleared away after the map had served its immediate purpose. It is curious that Fitzroy did not consider in these early days, when so little was known about forecasting and everything remained to be learnt, that it was worth while preserving a copy of his daily map for future study. It was not until 12 years later, in 1872, that a chart was added as a regular feature of the *Daily Weather Report,* though for five years before this charts had been drawn regularly and preserved within the Meteorological Office. It has been pointed out that the first maps were based on observations taken in Great Britain and France. It is well known that weather travels, and further that in this part of the globe it travels as a rule from west to east so that the weather which is perhaps causing shipwrecks in the Irish Sea to-day may yesterday have been far out over the Atlantic. The need for extending the system of reports to cover a wider area must have been felt at once, and it is of interest to trace the gradual extension of the area from which reports were received from the initiation of the service in 1860 to the present day.

In 1868 readings were first received from Corunna on the north-west coast of Spain, which to this day remains one of the most important of the European observing stations by reason of its position where the Iberian Peninsula juts out into the Atlantic and where the first effect of a disturbance advancing eastward from the ocean in that latitude is felt. In the following year observations were received from Norway and in 1873 from Sweden also. It was not until 1887 that the need of readings from central Europe seems to have made itself felt, reports from Berlin and other German stations being first received in that year. During all this time British meteorologists were working under a serious handicap, reports from the westward, that is from the most important quarter, being absent. This could not be allowed to continue for ever and some amelioration came in 1894 when daily readings from Ponta Delgada in the Azores first reached Europe. The Azores are in a region of the Atlantic usually dominated by a large anticyclone or area of high barometric pressure. Any disturbance of this high pressure system is likely to be followed later by an effect on European weather, and readings from this region have for long been regarded as indispensable to the forecast services of all European countries.

Twelve years later, in 1906, the meteorological observations taken in Iceland and the Faeroes became available to European meteorologists over the cables of the Great Northern Telegraph Company. Readings were now received from Iceland to the north-west of the British Isles and from the Azores

to the south-west. Between these there was a region of open water some 2,000 miles in extent over which most British weather takes its birth and the conditions in which could only be inferred from these readings to the north and to the south. There were plenty of ships ready to make observations constantly traversing the region but there were no means of communicating their readings to land. The advent of wireless telegraphy removed the hindrance, and in 1907 the first wireless weather reports were received in London from the ships of the Royal Navy, to be followed two years later by reports from Atlantic liners. For the first time British meteorologists were able to work with a weather map which was at least tolerably complete. There were still gaps to be filled but they were relatively small gaps compared with those which had previously hindered the work.

The position then before the meteorological services were disorganised by the war in 1914 was that reports were being received in London which enabled a fairly complete daily weather map to be drawn, covering an area from Norway and Spitzbergen in the north to the Mediterranean in the south and from the Azores and Iceland in the west to the confines of Russia in the east. The outbreak of war led, for a time, to a complete interruption of the exchange of meteorological reports between nations. The forecast work was to a large extent paralysed. At the same time it was found that the demands for forecasts in connexion with warlike operations were even more insistent than those made in times of peace and that the forecasts required, particularly those for aviation and gas warfare, were of a highly detailed character. Forecasts for such operations must be very definite. It was necessary, therefore, to re-establish the exchange of reports between allied and neutral countries as fully as possible, and to supplement this service by the establishment of a close network of reporting stations along the battle front from which reports of the weather changes from hour to hour could be passed to Headquarters. With these detailed reports available it was found that forecasts of the necessary precision could be issued. In this way invaluable experience was gained and when, after the termination of the war in 1918, a general resumption of the international exchange of weather reports became possible, this experience was not lost sight of. The system then built up has operated with detailed modifications only until the present day, and it may be useful to give a short account of it as showing the present stage of development of the daily weather maps used in forecast services.

Every country maintains a network of observing stations, there being about 600 in Europe and western Russia. Each of these stations makes one or more reports daily to its central office. The time of observation is fixed internationally. The principal hours used in Great Britain are 0h., 3h., 6h., 9h., 12h., 15h., 18h., and 21h.* by Greenwich time. Not every station can report at every hour. When the appointed hour draws near the observer goes out and notes the state of the sky, the amount and type of cloud which is present, whether it is raining or snowing, whether the visibility is good or bad. He also makes an estimate of the direction and strength of the wind unless he is provided with an anemometer or wind recorder from the record of which he can take the information. He then goes to his thermometer screen and reads the temperature and to his rain-gauge and measures the amount of rain which has fallen. Finally he reads his barometer and barograph. Each of these observations is entered in the notebook, but before transmission to Headquarters the readings have to be put into code. If any attempt were made to transmit the message without the use of a code it would be so long that the expense would be

*Until 1944 the "main" hours of observation were 1h., 7h., 13h., and 18h. and the charts which appear in the later pages of this book relate to one or other of these hours.

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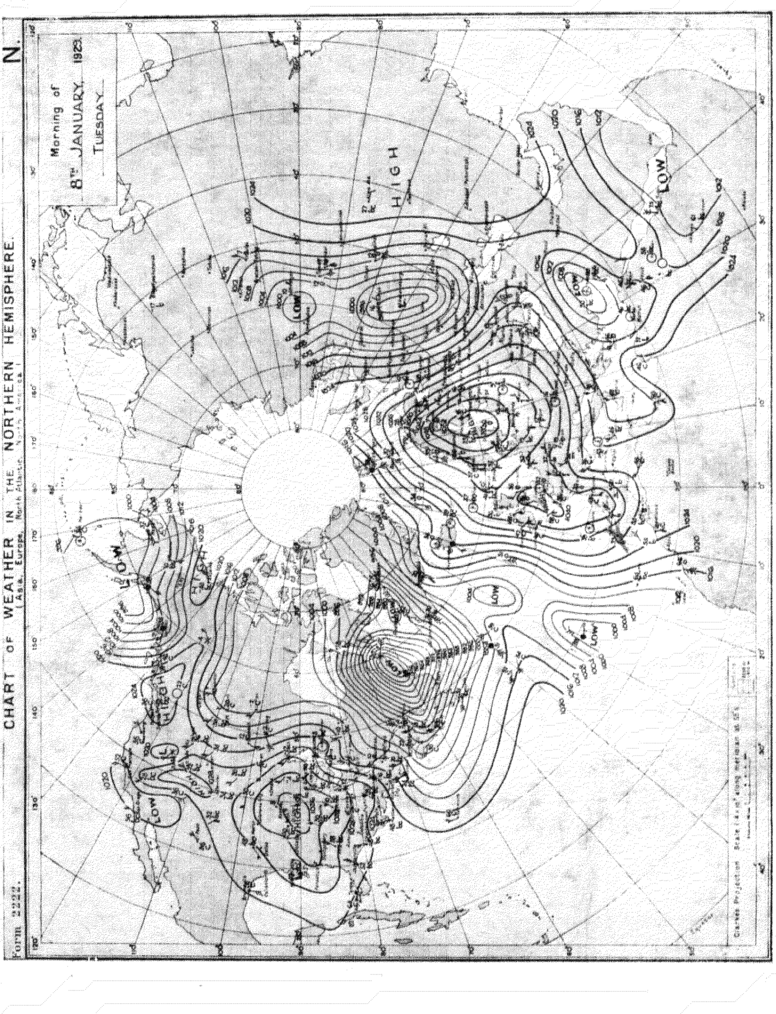


FIG. 3

prohibitive; also although it may seem strange to those unfamiliar with meteorological codes, the meteorologist at Headquarters would find much greater difficulty in obtaining the information he requires from a message in which the readings were set out one by one at full length than he does in dealing with a coded message, every figure of which has a definite significance to him. The code in use in nearly all European countries consists of five groups of five figures each. It is unnecessary to specify the method of coding in detail. Three figures are used for the height of the barometer, two for the wind direction, one for the wind force, two for present weather and so on. The coded message gives at a glance to its recipient almost as complete a picture of the weather in a distant place as the observer himself has obtained.

At the same hour the observers on board ship are recording their observations, and in coding them have to add also the position of the ship, since the readings would be of no use were it not known to which part of the ocean they referred. Messages when coded are despatched immediately by telegraph or by wireless telegraphy to the central meteorological offices of the different countries. They are received within less than an hour and the observations are entered at once on the weather map which is being prepared for the use of the forecaster. If the readings were used only within the country where they are taken this would be the end of the matter, but as we have seen forecast services are dependent on observations taken over a large area, and it is a well recognised duty of each country to issue its readings by wireless telegraphy from a high-power station so that reception may be made in all other countries within a radius of 1,000 miles or more. Not all reports are re-issued in this way. Each country makes a selection from among its stations of those which will serve to give a fairly complete picture of the weather conditions within its borders and re-issues reports from these only. The comprehensive messages containing these reports are termed "synoptic messages". Further, comprehensive synoptic messages are issued from certain high-power wireless stations comprising selected readings from large regions or zones covering many countries. The times at which the synoptic messages are broadcast cannot be left to chance, or confusion would result through many countries issuing their readings simultaneously. This matter has been the subject of international agreement, and a time-table has been laid down for the whole of Europe so that at no individual moment are more than two or at most three countries issuing their synoptic messages. As the wave-lengths employed in any two simultaneous broadcasts differ there is no jamming, and a meteorological service which is equipped with two or at most three receiving sets can obtain, within the course of one to two hours from the time of observation, reports covering the whole of Europe. Even a single receiving set will serve to provide the observations for quite a good weather map.*

Until recently no great need was felt in Europe for reports from across the Atlantic but with the advance of knowledge and with the demands for forecasts covering a longer period of time, some information regarding conditions in North America became desirable. The United States Weather Bureau has co-operated by issuing, twice daily from a wireless station of sufficient power to cross the ocean, a message giving short weather reports from a network of stations covering the whole of Canada and the United States with a few reports from the West Indies and the northern parts of South America. These messages, together with the readings already issued in Europe and Asia, enable a daily weather map covering a considerable part of the northern hemisphere to be prepared each morning. Such a map is drawn in London and is illustrated in Fig. 3 by the chart for the morning of January 8, 1929.

*The arrangements described in this paragraph have not yet been fully restored.

This represents the present stage of development of the daily weather map. As to the future the limit of development along the present lines seems to be the preparation of a daily map for the whole globe, an object which has already received international consideration, though its achievement may be delayed by practical difficulties. Almost every meteorological element which is of value in forecasting and which can be observed from the earth's surface is now observed and reported so that there is not much room for extension in the comprehensiveness of the reports. There is, however, one direction in which extension is desirable and indeed must come before forecasting can be developed to its full extent, and that is in the reporting and charting of observations taken in the free atmosphere above the earth's surface. The region of the atmosphere in which conspicuous meteorological changes take place is some 10-15 miles in thickness and while observations are made only from the ground many changes of fundamental importance which are taking place in the upper air may go unrecorded. The need for upper air observations is being met by reports from mountain stations, by the use of aeroplanes, by sending up small free balloons known as pilot balloons from observations of which the upper wind can be determined and by the use of radio-sondes for determining temperature, humidity and wind, and radar for wind.

CHAPTER II

The Observations, Pressure and Wind

The manner of entering readings on weather maps is not identical in all countries although possessed of a certain general similarity. No useful purpose would be served by going into the detailed differences; the method adopted in preparing the daily weather charts of the British Meteorological Office will be described here. Of all the different elements which go to make up a daily weather map, barometric pressure is generally regarded as the most fundamental and will be considered first. Wind is so closely associated with the distribution of barometric pressure that it will be convenient to deal with it in the same chapter. More than 90 stations are maintained in the British Isles which report weather conditions by teleprinter, telegram or telephone to the Meteorological Office for use in preparing the daily weather maps needed by the Forecast Service. Reports from each of these stations are necessary for forecasting, but a weather map could be prepared with fewer stations and it will simplify the explanation if for the present purpose we select about 20, well distributed over the country. The positions of the stations chosen are shown on the map, Fig. 4, on p. 11.

The pressure which the atmosphere exerts and which is measured by a barometer, although of so much importance in meteorology, is a somewhat intangible thing to many people. This is mainly due to the fact that the human body is adapted to live in air at a pressure equal to that which prevails on the earth's surface so that the existence of this pressure passes unnoticed. It is a well-known fact that water exerts a great pressure even at a moderate depth, and that divers working at some distance under the surface of the sea are subjected to great inconvenience owing to the pressure of the water around them. The sea of air which covers the earth exerts a pressure in exactly the same manner, but the weight of a given volume of air at normal pressure and temperature is only one eight-hundredth part of that of the same volume of water so that the pressure produced by air of a given depth is immensely less than that due to the same depth of water. The fact that air though light does produce a pressure can be shown by the following experiment. Take an

empty tin with a small orifice which can be closed by a cork, like the tins in which oil for bicycles is sometimes sold. Pour some water into the tin and boil this over a flame, leaving the cork out so that the steam can come out freely carrying with it the air contained in the tin. After steam has been given off freely for a short time, remove the tin from the flame and insert the cork tightly. It will be found that after a brief interval the tin will collapse. This is due to the fact that the steam inside rapidly condenses and as all the air has previously been driven out the pressure inside becomes much reduced. The air outside continues to exert its full pressure and the tin collapses under the strain.

The following line of argument will demonstrate why air does exert a pressure. Let a two-shilling piece be placed flat on the ground and consider the circular column of air extending upwards from this to the top of the atmosphere. A two-shilling piece has an area of one square inch which, for a reason which will be explained later, makes it convenient for this purpose. The weight of the column will be about 15 lbs. and the whole of this weight will be supported on the coin in just the same way as when a walking-stick is placed upright on the floor its weight is supported by that portion of the floor on which it rests. The coin then is subjected to a weight of about 15 lbs. on its upper side and if there were no air beneath it this force would be required to raise it from the ground. We have said that the area of the two-shilling piece is one square inch. The pressure exerted by a gas acts equally in all directions and the air thus exerts a pressure on objects with which it is in contact of 15 lbs. on every square inch. It does not of course require a force of 15 lbs. to raise the coin from the ground. This is because the small space existing between the ground and the coin is occupied by air and this air beneath the coin pushes it upwards as strongly as the air above pushes it down, and the force exerted passes unnoticed.

The pressure of the atmosphere is measured either by a mercury barometer or an aneroid barometer. The latter method will be considered first, as the illustration of the crushed tin which has been given shows directly the principle employed in the construction of this instrument. A hollow metal box of circular shape is covered at the top with a thin flexible sheet of metal, and, the joint being made tight, all air is extracted from inside the box. The pressure of the atmosphere acting on the top of the lid tends to crush it in and this force is balanced by a strong spring placed within the box pushing the lid upwards. When the air pressure increases it partially overcomes the resistance of the spring and moves the lid of the box in a little. When the pressure decreases, on the other hand, the spring forces the lid further out. The position of the lid is shown accurately by a pointer on a dial which thus indicates the barometric pressure. The aneroid type of barometer is convenient for many purposes owing to its light weight and portability, but it suffers from the defect that its readings do not remain accurate over a prolonged period and therefore for all meteorological work the mercury type is preferred. In this case the pressure exerted by the air is balanced by the weight of a column of mercury. It is not proposed here to describe the instrument in detail. It is only necessary to say that when barometric pressure is high it balances a higher column of mercury than when it is low, and that the barometer is so constructed that the height of the column which balances the air pressure can be measured accurately at any time.

The unit in which barometric pressure is recorded is a matter of considerable importance. Owing to the fact that this pressure is determined by measuring the height of a column of mercury and that the inch is the unit of length adopted in this country, pressures were formerly measured in Great Britain in inches of mercury. For the same reason millimetres of mercury were employed on the

continent. This lack of uniformity caused great inconvenience as readings transmitted from one country to another had to be converted from millimetres to inches or from inches to millimetres before they could be used. The Meteorological Office, therefore, in 1914 decided to discard the inch of mercury and to adopt a new unit, the millibar, a measure of pressure which is very convenient for the purpose, in the hope that it might ultimately take the place of both the millimetre and the inch and receive international acceptance. The millibar suffers from one defect: it has a most unfortunate definition. It is defined as a pressure of 1,000 dynes per square centimetre. Few people in this country can visualise the area described as one square centimetre and fewer still have any conception of the force expressed as one dyne. The definition, therefore, conveys nothing to the great majority of people. It is fortunately not necessary to bear the definition in mind if it is remembered that 1000 millibars (commonly written mb.) represents approximately the atmospheric pressure at the surface of the earth. This is good enough for all ordinary purposes and is moreover a very easy fact to remember. The ordinary fluctuations of barometric pressure in the British Isles range from about 970 mb. to 1030 mb., while readings as low as 925 mb. and as high as 1055 mb. may occur. All barometers used in the Meteorological Office are now graduated in millibars, and the readings are transmitted from observing stations to Headquarters in this unit. For the convenience of those who wish to convert a reading from millibars to inches of mercury or *vice versa* it may be stated that 1000 mb. equals 29·53 in. and 30 in. equals 1015·9 mb. The mercury barometer, though a reliable instrument, does not give the air pressure directly by its readings. It is necessary for the observer first to apply certain corrections before he obtains the true pressure at his station. In addition to these a very important correction has to be applied to reduce the reading to mean sea level before it can be used by the maker of a weather map in the central office. To show the need for this it is necessary to return for a moment to the illustration of the column of air above a two-shilling piece previously given. If the coin is placed at ground level it has to support the whole column of air to the top of the atmosphere which, as stated, weighs about 15 lbs. If it is placed on top of a mountain, the column of air above it will be shorter and its weight therefore less so that the force on the coin will be reduced by some 3 lbs. if the mountain is 5,000 ft. high. That is the air pressure on the mountain top will be 12 lbs. to the sq. in. instead of 15 lbs. Thus a barometer placed on a mountain will read lower than one placed at sea level and it is necessary to adjust the reading taken on the mountain before it is entered on the map. If this were not done the difference in the pressure readings at the several stations would be much more largely due to the differences in their height above the sea than to differences in the meteorological conditions. What is required is the reading which the barometer would have if it were placed in a deep valley contiguous to the station, the bottom of which was at sea level, supposing such a valley to exist. Fortunately a reading taken at some elevation above sea level can easily be reduced to give the reading at sea level by the use of a suitable table so long as the station is not at a height greater than about 1,000 ft., and few British reporting stations exceed this. For greater heights the reduction becomes less easy to determine. The readings taken are corrected to give the pressure at mean sea level in every case before being telegraphed to the Meteorological Office. On receipt they are entered by a draughtsman on an outline map of the British Isles on which the positions of the reporting stations are shown by dots. Those received in London on the evening of March 30, 1928, are shown in Fig. 4.

The readings being entered it is next necessary to draw isobars or lines of equal pressure. Isobars are very similar to contour lines on geographical maps and a short description of these contour lines may help to make the meaning

of isobars clear. Imagine a lake the surface of which is 100 ft. above sea level. Every point at the water's edge will be this height above the sea. If the lake is marked on a map its outline will be a contour line for 100 ft. above sea level. Mark 100 against this line. Now suppose that some water is run out of the lake so that the surface is lowered by 10 ft. The area will diminish and the new line marking the edge will form a closed curve within the former one to which it will be roughly parallel, though where the shore of the lake is

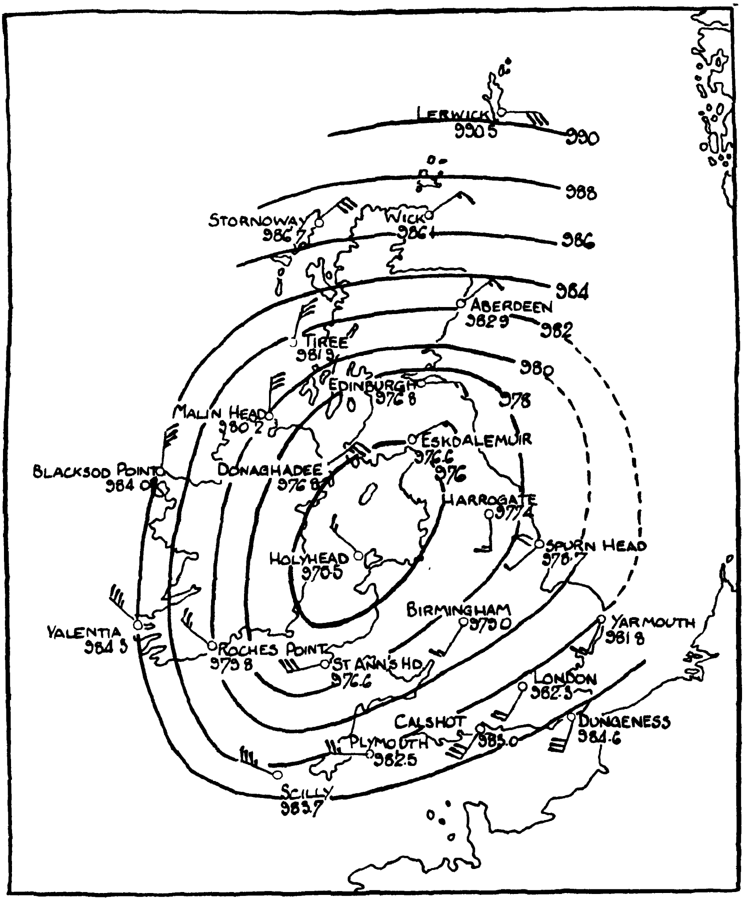


FIG. 4.—MARCH 30, 1928, 18H.

shelving there will be a greater distance between the two lines than where the shore is steep. This new line will pass through all places which are 90 ft. above sea level and may be marked 90. If the lake is drained by further successive steps of 10 ft. its boundary will mark out in the same way contour lines for 80 ft., 70 ft., etc., and these lines will form a set of roughly parallel closed curves. In the same way that contour lines are drawn through places having equal heights above sea level, isobars are drawn through places having equal barometric pressure and the isobars round an area of low pressure form a similar set of closed curves to the contour lines we have been considering.

An area of low pressure existed over the British Isles on the evening of March 30, 1928. If the pressure readings on Fig. 4 are examined, it will be seen that those over northern and central England, eastern Ireland and southern Scotland are below 980 mb., while those in the remaining parts of the country are above this figure. Between the regions where the pressure was below 980 mb. and those where it was above, there must have been places at which pressure was exactly 980 mb., since pressure varies uniformly from one place to another and does not go in jumps. We can therefore draw an isobar of 980 mb. surrounding the area mentioned above. It will pass very close to Malin Head in the north of Ireland where pressure is 980·2 mb. and to Roches Point in the south where it is 979·8 mb. It will then curve round, passing between the Scilly Isles and South Wales and reaching the North Sea a little south of the Wash. We are unable to determine its precise position over the North Sea and it is shown dotted in this region. It enters the British Isles again somewhere between Edinburgh and Aberdeen and passes across Scotland to the north of Ireland. This isobar is marked 980. Within it there will be another passing through places at which pressure is 978 mb. Only one station on the map, namely Holyhead, shows a pressure below 976 mb. though the reading at Eskdalemuir in the south of Scotland is not much above this figure. The area covered by the isobar for 976 mb. therefore will not be large but will include most of the Irish Sea. Isobars for values higher than 980 can be drawn in a similar manner.

The method of determining the correct position in which to draw an isobar will be made plain by the following example. Consider the east coast of Scotland on the map in Fig. 4. The pressure at Aberdeen is 982·9 mb. and at Wick 986·1 mb. The isobar for 986 will pass therefore very close to Wick but a trifle to the south of it. Now take a direct line from Aberdeen to Wick and consider the place on it which has a pressure of 984 mb. This place must lie rather nearer to Aberdeen than to Wick. Actually its pressure will differ from that at Aberdeen by 1·1 mb. and from that at Wick by 2·1 mb. and its distances from the two places must be in the same proportion. It will therefore be about one third of the way from Aberdeen to Wick, and if a dot is marked in this position the isobar for 984 must pass through this dot. Similar dots can be placed between other pairs of stations which have pressures above and below 984 respectively, and a freehand curve drawn through these dots will form the 984 isobar. In learning to draw isobars it may at first be useful actually to mark the dots on the map but after a time sufficient skill is obtained to enable the lines to be drawn on inspection of the pressure readings with great rapidity.

The next element which will be considered is wind. We will return to the work of the observer, leaving Headquarters for a time. In observing wind account must be taken both of direction and speed, for measurement of the one without the other would be insufficient. The wind is never entirely steady. It is always made up of a series of gusts and lulls though these variations may be large, when the wind is said to be gusty, or small when it is steady. Gusts are caused by trees, houses, or in fact by any obstruction to the free flow of the air. Even the slight resistance to free flow imposed by passage over a water surface causes some gusts though these are of smaller magnitude than those produced by broken land. Larger obstructions such as cliffs and mountains not only make the wind gusty but may deflect it from its true direction. Every obstruction tends to reduce its speed. It is for these reasons very important when choosing a meteorological station to obtain a site with an open exposure, where the wind will approximate as nearly as possible to the true wind which would blow if there were nothing to hinder its course. Such sites may not infrequently be found on the sea coast provided there are

not high cliffs, but are less common inland, and it is very necessary when using weather charts to remember that an observation of wind may be influenced to a considerable degree by the nature of the country in which the observing station is situated.

The direction of the wind is always specified by quoting the point *from* which the air is moving ; thus a S. wind is one in which the air blows from the south towards the north and not *vice versa.* The directions used in meteorological work are true or geographical directions and not magnetic or compass directions. The difference between the two north points, geographical north and magnetic north, is not constant over the British Isles neither does it remain constant from one year to another. At the present time (1928) the magnetic compass points to about 14° west of true north over England and about 17° or 18° west over Scotland and Ireland. Where the points of the compass are indicated beneath weather-cocks, the pointers have frequently been set to magnetic directions at some past date and may be misleading if used to determine the wind direction. For another reason the ordinary weather-cock is often an untrustworthy guide. It frequently fails to move readily on its bearings and requires a strong wind to turn it, so that in light or moderate winds it may give quite an incorrect indication. For this reason it is much better where no reliable instrument is available for reading the direction of the wind, to take the indications of smoke or a flag in as unobstructed a situation as can be found and not to trust to weather-cocks.

The speed of the wind may be estimated from the appearance of objects like trees which are moved by it though more precise information can be obtained from an anemometer, an instrument designed to measure wind, provided that the instrument is of a reliable pattern and well exposed. Sailors have long been experienced in estimating wind force, and so long ago as 1806 a scale was put forward by Admiral Beaufort which with but slight modification has been in general use ever since. Admiral Beaufort's original specification was based upon the sails which a man-of-war could carry under certain conditions. Such a description has little meaning at the present day and its place has been taken by that given in the following table in which are set out in the several columns :—

(1) the Beaufort numbers,

(2) the names attached to the several numbers,

(3) the type of arrows used to indicate the different forces on weather maps,

(4) the average speed of the wind in miles per hour, and

(5) the effect of the different winds on objects such as smoke and trees.

The scale runs from 0, a calm, to 12, a hurricane. The terms light, moderate, strong gale, etc., which occur in the scale are in common use and are well understood.

A word of explanation is necessary with regard to the equivalent velocities given in the table. The velocity of the wind varies with height above the ground, the wind at 60 ft. is a good deal stronger than the wind at 20 ft. or 30 ft. It is therefore necessary to specify the height to which the velocities refer. This height is 33 ft. The equivalents were determined from long series of estimates made by experienced observers in close proximity to reliable and well-exposed anemometers from which the velocity could be read.

THE BEAUFORT WIND SCALE

Beaufort No.	*Wind*	*Arrow*	*Speed* m.p.h.	*Commonly observed effects of corresponding winds*
0	Calm	$\odot$	0	Calm, smoke rises vertically.
1	Light air ..		2	Direction of wind shown by smoke drift, but not by wind vanes.
2	Light breeze ..		5	Wind felt on face; leaves rustle; ordinary vane moved by wind.
3	Gentle breeze ..		10	Leaves and small twigs in constant motion; wind extends light flag.
4	Moderate breeze		15	Raises dust and loose paper; small branches are moved.
5	Fresh breeze ..		21	Small trees in leaf begin to sway, crested wavelets form on inland waters.
6	Strong breeze ..		28	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	Moderate gale ..		35	Whole trees in motion; inconvenience felt when walking against wind.
8	Fresh gale ..		42	Breaks twigs off trees; generally impedes progress.
9	Strong gale ..		50	Slight structural damage occurs (chimney pots and slates removed).
10	Whole gale ..		59	Seldom experienced inland; trees uprooted; considerable structural damage occurs.
11	Storm		69	Very rarely experienced; accompanied by widespread damage.
12	Hurricane ..		above 75	—

Having discussed some of the points which are of importance in the measurement of wind one may return to the work of the observer. He estimates the force of the wind on the Beaufort scale, being careful that his estimate is the average wind over a few minutes and is not based on a momentary gust or lull. If his station is equipped with a well-exposed anemometer he takes the reading from that in miles per hour and converts it to Beaufort number from a table of equivalents which is supplied to him. He also observes the wind direction. The direction and force are included in the telegram to Headquarters and are there plotted on the weather map in the manner shown in Fig. 4. The wind arrow points towards the station, that is an easterly wind is shown by an arrow on the right of the station, a northerly wind by an arrow running down to the station from the top of the map and so on. The strength of the wind by the Beaufort scale, often known as the Beaufort force, is shown by the number of feathers on the arrow. Each feather on the wind arrows signifies two Beaufort force numbers and a short or half feather single forces. One or two examples will make the matter clear. In the Shetland Islands the wind is from the E. of force 6; at Blacksod Point in the north-west of Ireland it is from the N. of force 7 and at Dungeness in the Straits of Dover from SSW. of force 6.

It will be noticed at once that the winds on the map are closely related to the system of isobars, circulating round the region in the Irish Sea where barometric pressure is low in a direction opposite to that shown by the hands of a clock, that is in a counter-clockwise direction. In addition to this circular or roundabout motion the winds have a slight inward component across the isobars towards the region of low pressure. It may seem curious that the wind does not blow directly towards this region. If two closed vessels, one of which contains air at high pressure and another at low pressure are connected by a straight pipe the air will flow rapidly from the high-pressure vessel to the low and it would seem natural for air on the earth's surface in the same manner to flow from a region of high pressure directly towards one of low. This would be the case did not the earth rotate about its axis. It is owing to this rotation that the air flows more nearly around a region of low pressure than towards the centre. The reason why this should be so will be considered in the next chapter.

The rule followed by the wind was enunciated in 1857 by Professor Buys Ballot of Utrecht, in a law which bears his name and which states that in the northern hemisphere if you stand with your back to the wind, pressure is lower on your left hand than on your right. In the southern hemisphere the opposite is true ; stand with your back to the wind, pressure is lower on your right hand than on your left, so that the wind circulates round a low-pressure area in the southern hemisphere in a clockwise instead of a counter-clockwise direction. This makes southern-hemisphere weather maps very puzzling to those who are used to dealing with northern-hemisphere conditions only. If Fig. 4 is again studied it will be seen that not only is the wind direction obedient to the pressure distribution but the wind force is also dependent upon the isobars, being stronger where the isobars are close together than where they are far apart. The proportionality is not a very close one. We should not expect it to be owing to the differences which occur in the exposure of observing stations, and also owing to the fact that the isobars can only be positioned roughly we do not know exactly their distance apart in any part of the map. It is clear, however, that in the south-west of England and over Ireland where the isobars are close winds are much stronger than over the north of England where the isobars are more widely spaced, and study of weather maps shows that the rule is generally true. The reasons lying behind this rule will also be considered in the next chapter.

The system of isobars and winds shown in Fig. 4 form a "depression" or "low" so called because barometric pressure is depressed or low within the system. This is one of the most important of all pressure types owing to its frequency of occurrence and to the fact that most occasions of strong wind and rain in temperate latitudes are associated with depressions. An older name for these systems was "cyclone," a term which is still sometimes used though it has come to be employed more commonly for the violent circular storms of tropical regions, and it is preferable that its use should be confined to these storms. Other pressure systems will be described in a later chapter when the weather associated with the different types is being considered.

CHAPTER III

Relation of Wind to Pressure

It was pointed out in the last chapter that there is a close relation between wind and barometric pressure, the wind tending to blow along the isobars but with a small deflection towards the side of low pressure and tending to be strong where the isobars are close and weak where they are far apart

Attention was also directed to the fact that the observations of wind made on the surface are likely to be affected by local obstructions which deflect the flow of air in the neighbourhood of the station. If there is a connexion between the wind and the isobars we should therefore anticipate that it would be more clearly shown in the winds blowing at some height above the surface where the effect of obstructions is small, say, at one or two thousand feet, than in the winds at the surface. Such is actually found to be the case. In this chapter we shall consider what relation might be expected to obtain between the wind and the pressure distribution. Before doing so it will be necessary to consider what is meant by the term " pressure gradient." The word " gradient " is commonly used in ordinary life to denote the slope of a hill. In this case it indicates the rise of the ground over a certain horizontal distance. Thus if a hill has a gradient of 1 in 10 it means that the road surface rises at the rate of 1 ft. for every 10 ft. traversed horizontally. The word has a similar meaning when used in association with pressure, the pressure gradient being the change in barometric pressure per unit horizontal distance and being always measured in the direction in which pressure changes most quickly. It will be seen that this direction is that at right angles to the isobars. Pressure gradient is then the change of pressure per 100 miles or other convenient distance measured perpendicularly to the isobars. By analogy with road gradients, when the change of pressure is large over a given distance the pressure gradient is said to be steep. When the change of pressure is small the gradient is slight. When measuring a pressure gradient from an isobaric chart the most direct method might seem to be to take two places 100 miles apart and measure the pressure difference between them. In practice as isobars are always drawn on pressure maps it is more convenient to measure the distance between two consecutive isobars and to determine the pressure gradient by dividing the pressure difference between the two lines by this distance. A pressure gradient cannot exist without a force being imposed on the air which is constantly being pressed from the region where pressure is high to that where it is low. If the earth did not rotate upon its axis this would result in a wind current being set up from high to low pressure, and as the wind current would be constantly accelerated by the pressure gradient acting behind it the speed of the air after a short time would become very high. The rush of air from the region of high pressure to that of low would soon equalise the pressure in the two places and the pressure systems which in actual fact govern all the weather of temperate latitudes on the earth could not exist. The effect of the rotation of the earth on its axis is, however, a matter of supreme importance and completely alters the situation. The effect of this rotation is to cause every body which moves freely over the earth's surface with no force upon it but that of gravity to turn to the right in the northern hemisphere and to the left in the southern hemisphere. It is not difficult to see why this should be so.

Imagine a smooth earth such as would obtain if the terrestrial globe were entirely covered by water and this were frozen. Place a ball on this surface and give it a push in some direction. We will assume that the smooth surface of the ice would offer no resistance to the motion (which would not actually be the case) and that there is no air resistance. If the earth did not rotate the ball would roll in a straight course over its surface and after traversing a great circle, that is a line round the full circumference of the sphere, it would return to the starting point. Now consider the case of a rotating earth. Every point on its surface rotates about the polar axis but the velocity of rotation depends upon the distance from the pole. Points on the equator are moving towards the east at 1,050 miles per hour while the North Pole itself being on the axis has no movement. Each point at an intermediate latitude has its

own speed of rotation. London, for example, is moving east at the rate of 650 miles per hour; Peterborough about 1° north of London being rather nearer the polar axis, is moving more slowly. Its speed is 14 miles per hour less. Imagine the ball pushed northwards from London at a speed of 30 miles per hour. It will have this speed northward and also will share with London the velocity eastward of 650 miles per hour though this eastward movement would not be noticed by an observer on the earth because he himself would be moving with the same speed. As the ball moves over the smooth surface of the earth it will retain both these velocities so that when it reaches Peterborough or the neighbourhood of Peterborough, it will be moving northward at 30 miles per hour and to the east 14 miles per hour faster than the ground under it. The ball would then appear to anyone in Peterborough to be moving at 14 miles per hour to the east in addition to its original northward movement. It will therefore no longer be moving to the north but somewhat to the east of north, that is its path will have turned to the right. If we had started the ball at Peterborough by a push to the southward, when it reached the neighbourhood of London its speed to the east would have been 14 miles per hour less than that of the ground under it and it would appear to move to the west, that is it would again have turned to the right. The same thing would happen if the ball were pushed to the east or west though the reasoning in this case is somewhat different. If the ball were given a movement to the east it would be moving rôund the polar axis of the earth more rapidly than the earth itself and the centrifugal force which tends to throw any body which is rotating about a point away from that point would act upon it more strongly than upon an object which was stationary upon the earth's surface. It is like a weight swung on the end of a string, the faster the rotation the greater the pull. The centrifugal force would tend to throw the ball out into space but the pull of gravity towards the earth's centre would prevent it leaving the surface and the resultant force would push it towards the equator so that in addition to its movement towards the east it would also acquire a movement towards the south, that is it would turn to the right. A ball moving to the west would conversely have a smaller centrifugal force upon it than one which was stationary and would thus tend to move towards the pole. Again it would turn to the right. It will be clear from this reasoning that all bodies moving over the earth's surface in the northern hemisphere are deflected to the right. It is not, however, clear that the deflection will be the same for a body moving east as for one moving south. Calculation shows that this is the case and that all bodies moving over the earth in the northern hemisphere behave as though a force were constantly bearing upon them to the right, the magnitude of this force being proportional to their velocity of travel over the earth's surface and to their weight. The force also depends upon their position on the earth, being greatest at the pole and falling to nothing at the equator.

Air at 1,500 ft. above the earth's surface where the disturbing influence of trees and hills is not felt moves freely in just the same way as the ball which we have considered and is therefore subject to this force acting towards the right, proportional to its speed of travel. When there is a pressure gradient existing the air is also subject to the force imposed by this gradient. In accordance with the well-known law of Newton a body can only continue to move at the same speed in a straight line if the forces acting upon it balance one another, and the air can therefore only continue in a straight course over the earth if the force due to the pressure gradient balances that due to the earth's rotation. We have seen that the latter force always acts perpendicularly to and in the northern hemisphere to the right of the direction in which the air is moving, and as two forces cannot be balanced unless they act in opposite directions along the same line, pressure gradient must also be directed

perpendicularly to the air movement but to the left, that is the air must be moving along the isobars with low pressure on the left, or it cannot continue on a straight course without change of speed. Further its velocity must be such that its tendency to turn to the right which is directly proportional to the velocity just balances the force due to the pressure gradient which presses it to the left. When this happens the wind is said to be "geostrophic." If the pressure gradient is steep it will impose a large force on the air and this can only be balanced if the velocity is great, with a correspondingly large force tending to turn the air to the right. We thus see that geostrophic winds corresponding with steep pressure gradients are strong and those corresponding with slight pressure gradients are light.

We have seen that when the wind has its geostrophic velocity and blows parallel to the isobars with low pressure on its left hand in accordance with Buys Ballot's law, it will continue to move in a straight path without change of speed. Such conditions cannot in practice continue unless they are what is called stable, that is unless when the air movement is disturbed in any way it tends to return to its former speed and direction. Such a disturbance must take one of the following forms. The air may be deflected to the left or to the right or its speed may be either increased or decreased. Should there be a deflection to the left the air would commence to travel towards the region of low pressure and having the high pressure at its back its speed would be increased. This would lead to an increased tendency to turn to the right and thus to a return to the old path along the isobars. In the same way if the deflection is to the right the air will be pushing its way into the area of high pressure and lose speed. The force to the right will accordingly diminish and again the air will be deflected back to its old path. Any disturbance in its velocity leads to the same result. If the velocity is increased it will turn to the right and as it moves towards the high-pressure region will slow down. If its velocity is decreased it will turn to the left and be speeded up. Thus any departure from the geostrophic motion does not tend to increase but to decrease and the condition is stable. While it may be admitted that this is the case some doubt may be felt whether the air in practice would ever attain to the geostrophic condition, and it will be worth examining what would happen if a pressure distribution were built up in a region where the air was calm. The air would at first commence moving from the high pressure to the low in a direct line with increasing velocity. While it moved in this direction there would be nothing to prevent the rotation of the earth causing it to turn to the right, which it would accordingly do, and this turning would continue until its velocity reached the geostrophic rate and its direction was along the isobars. It would actually in the course of a few hours attain the geostrophic state.

It has been mentioned that the tendency to turn to the right is dependent, upon the latitude, being large at the poles and zero at the equator. The geostrophic wind therefore also varies with the latitude. The table attached gives the relation between the pressure gradient and wind in different latitudes from the equator to the pole. Pressure gradients are shown by the distance between consecutive isobars differing in value by two millibars and the air is taken as being of normal density. The density of air depends upon its pressure and temperature and if these are such that its density is not normal, a small correction will have to be applied to the geostrophic wind but this is a refinement into which it is not proposed to enter here.

To use the table proceed as follows. Take the line which corresponds with the latitude of the place, following this across until the column is reached at the head of which the correct distance apart of 2 mb. isobars is found. At the intersection of this line and column the appropriate geostrophic wind is

given. Thus in latitude 50° if the isobars are 50 miles apart the geostrophic wind will be 40 miles per hour. If they are 100 miles apart, that is if the pressure gradient is half as steep the wind will be half, i.e. 20 miles per hour. It will be noticed that as the equator is approached the winds corresponding with even a moderate gradient become very strong, and as such winds cannot easily exist steep pressure gradients are never experienced in equatorial regions except in the violent cyclonic storms to which reference is made below. Values in excess of 150 miles per hour are not included in the table for geostrophic winds of this value seldom or never occur.

TABLE OF GEOSTROPHIC WIND (Winds in m.p.h.)

Lat.	Distances between consecutive 2 mb isobars in miles												
	20	25	30	35	40	45	50	60	80	100	150	200	300
0°	—	—	—	—	—	—	—	—	—	—	—	—	—
10°	—	—	—	—	—	—	—	147	110	88	59	44	29
20°	—	—	149	128	112	99	89	74	56	45	30	22	15
30°	—	122	102	87	76	68	61	51	38	30	20	15	10
40°	119	95	79	68	59	53	48	40	30	24	16	12	8
50°	100	80	66	57	50	44	40	33	25	20	13	10	7
60°	88	71	59	50	44	39	35	29	22	18	12	9	6
70°	81	65	54	46	41	36	32	27	20	16	11	8	5
80°	78	62	52	44	39	34	31	26	19	16	10	8	5
90°	76	61	51	44	38	34	30	25	19	15	10	8	5

The speeds given in the table refer to air of normal density (·00125 gm./c.c.) at 1016 mb. pressure and 50° F. temperature.

In the argument of this chapter it has been assumed that the air is following a straight path over the surface of the earth or more strictly that it is moving in a great circle. Actually air seldom moves along a great circle but follows a curved path, for example round a depression. It is then subject to centrifugal force away from the point about which it is revolving like any other body moving in a curved path and if it is to continue moving in the curve the pressure gradient must balance this centrifugal force as well as the tendency to turn to the right. When account is taken of this the calculated wind is called the gradient wind instead of the geostrophic wind and the component of the force due to the centrifugal action is called the cyclostrophic component. The gradient wind like the geostrophic wind blows along the isobars with low pressure to the left in the northern hemisphere. When dealing with the violent circular storms of small diameter known as hurricanes which occur in tropical regions, it is essential to take account of this cyclostrophic component. It is in fact of so great importance that the geostrophic component need hardly be considered and the balance of forces is almost entirely one between pressure gradient and centrifugal force. In temperate latitudes on the other hand it is seldom that the path of the air is sufficiently curved to render the cyclostrophic component of any importance, and it is found in practice that in the majority of cases it can be disregarded and that the geostrophic wind gives a close approximation to that which actually blows at a height of about 1,500 ft.

Surface winds which are subject to the retarding effect of trees and other obstructions have their velocity reduced below the geostrophic value. This reduction leads to a decreased tendency to turn to the right, and the pressure gradient which acts on the surface air as strongly as on that above forces the air in towards the region of low pressure. Surface winds should therefore have

a lower velocity than those above and have an inward movement across the isobars towards the side of low pressure. Study of weather maps shows that this is in general the case though faulty exposure to wind at individual stations and other reasons prevent the rule from being invariably true in every individual case.

CHAPTER IV

The Observations, Temperature and Weather

The next element for consideration is temperature. Air temperature in this country is generally recorded in degrees Fahrenheit, and all readings given here will be in this unit. In measuring the temperature it is important to ensure that the thermometer is properly screened from any source of heat, such as direct sunshine, or accurate readings cannot be obtained. For this reason it is necessary to place thermometers used for meteorological work in some kind of screen or enclosure. In England the Stevenson screen has for many years past formed the standard method of protection. There has been no world uniformity of system, and in tropical countries a thatched roof to keep off the sun's rays has found favour. Comparison of the different methods has recently shown that the Stevenson screen gives as good or better records than any other which is adapted for everyday use at a meteorological station, and this screen is now being employed in tropical countries as well as in the British Isles. The standard Stevenson screen consists of a box measuring 18 in. in length by 11 in. in depth with a height of 16½ in. supported on four legs 3 ft. 6 in. above the ground. The sides of the box are made of double louvres so that while air can pass freely through them, no direct or reflected rays from the sun can enter. The screen is painted white to minimise the heating effect of the sun on its outer surface. Of equal importance to the choice of the right type of screen is the need for obtaining a suitable site for its erection. Too great proximity to buildings is to be avoided as buildings are liable to affect the temperature of the air in their neighbourhood. A small walled-in garden is also an undesirable site, the air in such an enclosure tending to remain stagnant and to be unduly heated by day and cooled by night. Further the screen should not be placed under trees, which have a considerable influence on the air temperature beneath them. It is as a rule desirable that the most open site available should be chosen.

It was stated above that the screen is raised on legs 3 ft. 6 in. above the ground. This brings the bulbs of the thermometers to a height of about 4 ft. This figure is a matter of convention, but it is of importance if readings from different stations are to be comparable that the thermometers should be placed at the same height in all cases. This is because temperature sometimes varies greatly with height above the ground. For example on a hot sunny day the heated soil will warm the layers of air in immediate contact with it and the temperature will decrease rapidly in the first few feet. The converse holds to an even more marked degree on a cloudless night when the ground loses heat by radiation to the sky and becoming cooled, lowers the temperature of the air in the lowest layers. In either of these cases a thermometer at one or two feet height would give a different reading from one at four feet.

If the points enumerated above are attended to in choosing the position of the thermometers a reliable record of the temperature at the station will be obtained which will be satisfactory for comparing one day with another and one place with another. In forecasting, however, temperature reports are put to a more exacting use than this, and we shall see that considerable care is then necessary in interpreting the readings. It will be pointed out in a subsequent chapter that in modern forecasting considerable importance is attached to

whether a given mass of air is cold air which has travelled from polar regions or warm air from equatorial regions, these having widely different characteristics. It may be thought that it would be sufficient for this purpose to note whether the wind is blowing from a northerly direction or a southerly direction but this is not so, for air from polar regions may, after travelling southwards, curve round and reach a place as a southerly wind, while air from equatorial regions may in a similar manner arrive from the north. It is therefore not sufficient to know from which direction the wind is blowing to decide whether the air is polar or equatorial in origin and it is necessary to study other characteristics, of which one is temperature. For this purpose the readings of thermometers in the normal screen are not entirely satisfactory ; temperature readings in the free air at some considerable distance above the ground are really needed. There are several reasons for this, which will be discussed in the succeeding paragraphs. The first is concerned with the heating by the sun in the day and the cooling by radiation at night.

In Fig. 5 the temperatures at 13 h. on July 15, 1928, have been entered on a map and isotherms have been drawn. Isotherms are lines passing through places which have the same temperature and show regions of high and low temperature in the same way that isobars do regions of high and low pressure.

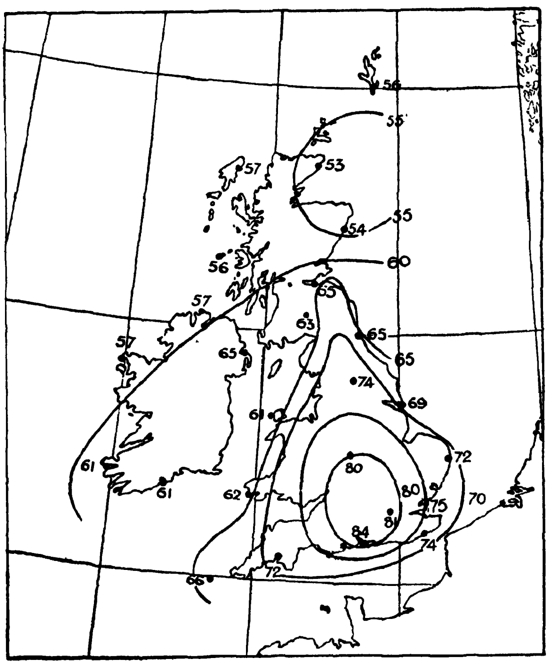


FIG. 5.—July 15, 1928. 13h.

We see that temperature reached or exceeded 80° in a few places in the south of England while in Ireland the readings did not exceed 65° and over most of Scotland temperature was below 60°. The lines bring out clearly the region of high temperature in the south of England and inspection will show that the isotherm of 70° follows roughly the coast line of England, inland temperatures being above this figure and temperatures over the sea below it. Such a distribution of temperature is common on hot summer days. The sun shining

on the surface of the earth heats it greatly so that it may even be unpleasant to hold the hand on the soil. If a shallow hole is dug in the ground it will be found that the heat is concentrated in a very thin layer of earth, the soil being a bad conductor of heat. The full heat received from the sun, therefore, goes to raise the temperature of one thin layer and this in turn heats up the air in contact with it and so produces the high temperature at inland stations. Over the sea conditions are different. The same heat is received from the sun but it is absorbed by the water which is nearly always in motion, the surface layer being constantly intermingled with those below so that instead of the full heating effect being concentrated on a layer a few inches thick, it is distributed in a layer of water, the thickness of which may be measured in feet or even in yards. Added to this the specific heat of water is high, that is a great deal of heat is required to raise its temperature through one degree. For these reasons the sunshine changes the temperature of the surface of the sea very little and the heat is not conveyed to the air over the sea as it is to the air over the land. Places on the coast thus fail to record the high day temperatures of those inland, and if temperature is read soon after midday, as in the readings shown on Fig. 5, the isotherms will mark out the inland regions from the coastal districts.

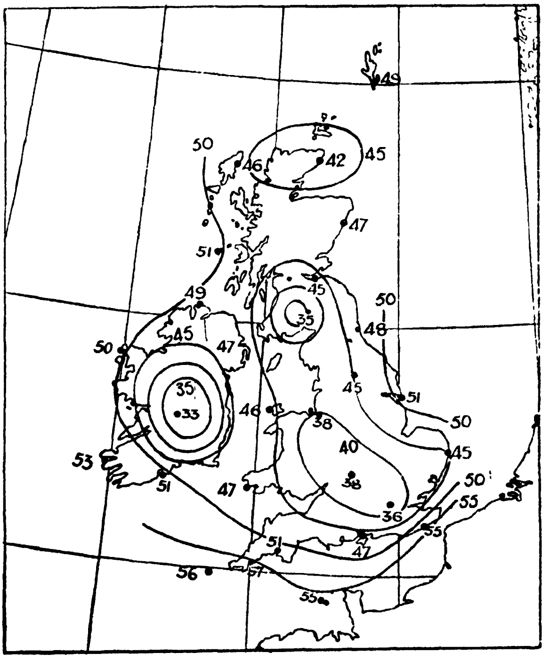


FIG. 6.—September 27, 1928. 7h.

The converse is true after a clear night. The surface of the earth radiates its heat to the sky and the small conductivity of heat through soil prevents further supplies of heat coming up readily from the lower layers so that the surface becomes intensely cooled. The sea surface on the other hand, with its big reserves of heat from below changes its temperature but little, and we find that the temperature at inland places falls much below that on the coast, particularly if a slight breeze from the sea is bringing air from the water

over the coastal regions. The temperatures taken at 7h. on September 27, 1928, and entered on Fig. 6 show this effect clearly. At many inland stations the reading was below 40° whereas on the coast the temperature was for the most part between 45° and 50° and at the Cornish stations, where the air was blowing from the warm waters of the English Channel, the readings were as high as 56° and 57°. Here again the isotherms show the land and sea effect in a predominating manner.

The two cases which have been illustrated in Figs. 5 and 6 were chosen to show the effect of solar heating by day and radiation cooling by night to a marked degree. They show that the temperature read at a meteorological station may give a good indication of the position of the station relative to the sea, but suggest that it would be futile to expect to learn whether the air had originated in polar or equatorial regions from its temperature as read by a meteorological observer. This is not entirely the case as the examples which have been chosen are extreme, but in general great caution is needed in using temperatures taken at the earth's surface as an indication of the source of origin of the air mass.

In mountainous countries a further difficulty is encountered. It is well known that temperature decreases with height above sea level, and that it is colder on a mountain top than on low ground in the vicinity. Temperature thus falls off with increasing height in the same way that air pressure does but there is an important difference, for the air pressure at a given height is connected with the pressure at sea level by a perfectly definite and well understood law whereas no rule can be given for the temperature change. All that can be said is that on an average temperature decreases by about 3° for every 1,000 ft. rise so that we should expect a station at 1,000 ft. above sea level to have a temperature some 3° lower than one at sea level. This decrease is not sufficient materially to affect the readings in Great Britain where few reporting stations are at any great height above the sea, but in mountainous countries like Switzerland or Norway it is necessary to apply some correction to the temperature readings obtained at high-level places before comparing them with those taken at other places at a lower level. This introduces yet a further cause of uncertainty in interpreting the readings.

The heating of the air by day and cooling by night which have been referred to at some length above are mainly confined to the surface layers, and if readings could be taken at one or two thousand feet above the surface these effects would be absent and the true temperature of the mass of air would be obtained. The fact that the temperatures referred to some height above the ground and not to the surface would be borne in mind, and there would be no need to attempt to correct them to surface level. Such readings would give a valuable indication of the polar or equatorial origin of the air and plotted on a weather map would be of much more value for forecasting than those taken at the surface.

We now come to "weather" using the term to include the degree of cloudiness of the sky, precipitation in the form of rain, snow, sleet or hail, squalls, thunder and lightning, atmospheric obscurity, i.e. fog, mist or haze, and ground phenomena like dew and hoar-frost. In order that these may be entered readily in the observer's register and on a weather map it is necessary to employ abbreviations of the names or symbols. Such a system of abbreviations was devised by Admiral Beaufort, the inventor of the Beaufort scale of wind force, in 1806 and employed by him at sea for many years. As a result of experience he introduced various modifications, and by 1830 the system had taken the form which with a few additions is in use to-day. The scale is set

out in the table on p. 25. It will be seen that most of the phenomena are indicated by the first letter of the name, thus b is used for blue sky, o for overcast, r for rain, s for snow, and so on. There are necessarily a few exceptions; d cannot be used both for drizzle and dew; it is employed for drizzle while dew is indicated by w. In the same way h is used for hail while haze is z. When the weather over a wide area is entered on a weather map in Beaufort letters it is difficult to pick out the individual phenomena without close study, and a system of symbols is therefore in use for the more important elements. The symbols are designed to catch the eye and to stand out readily on a map. A few of them are shown in the table on the following page. The weather

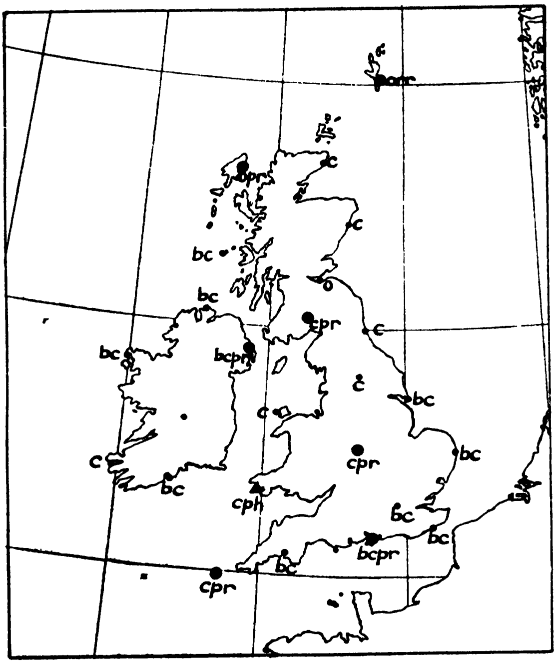


FIG. 7.—March 30, 1928. 18h.

on the evening of March 30, 1928, the occasion for which pressure readings were plotted in Fig. 4 (p. 11) is shown in Fig. 7. Beaufort letters are entered against each station and in addition where a symbol is appropriate this symbol is shown. The black dots at stations where rain was falling stand out clearly, and the triangular symbol at St. Ann's Head near Pembroke in South Wales indicates that hail was falling at that station.

The system of Beaufort letters as set out in the table makes no provision for recording the intensity of the different phenomena; such provision exists but for simplicity has been omitted. Meteorologists are accustomed to use capital letters on any occasion when the element reported is heavy or intense and the suffix $_o$ when it is slight. Further the letters are repeated to indicate continuity so that continuous rain will be entered as *rr* as in the case of Lerwick in the Shetland Islands in Fig. 7.

THE BEAUFORT LETTERS AND INTERNATIONAL SYMBOLS

(1) Appearance of Sky

b		Blue sky whether with clear or hazy atmosphere.
c		Cloudy, i.e. detached opening clouds.
o		Overcast, i.e. the whole sky covered with one impervious cloud.
g		Gloom.
u		Ugly, threatening sky.

(2) Wind

q		Squalls.
KQ		Line squall.

(3) Precipitation

r	●	Rain.
p	▽	Passing showers.*
d	❟	Drizzle.
s	✱	Snow.
rs	● ✱	Sleet.
h	▲	Hail.

(4) Electrical Phenomena

t		Thunder.
l	<	Distant lightning.
tl		Thunderstorm.

(5) Atmospheric Obscurity and Water Vapour

f fe	≡	$\left.\begin{array}{l}\text{Fog}\\ \text{Wet Fog}\end{array}\right\}$ Range of visibility less than 1,100 yards.
z	∞	Haze, range of visibility 1,100 yards or more, but less than 2,200 yards.
m	=	Mist, range of visibility 1,100 yards or more, but less than 2,200 yards.
v		Unusual visibility of distant objects.
e		Wet air, without rain falling.
y		Dry air.

(6) Ground Phenomena

w	⌓	Dew.
x	⊔	Hoar-frost.

The elements so far considered, pressure, wind, temperature and weather, almost complete the list of those which were regarded as necessary for the preparation of a daily weather map before the war. There was, however, one other, and that of no small importance, namely, barometric tendency. It is well known that when the barometer is rising there is a better chance of fine weather than when it is falling, and the official forecaster who works with a weather map is not blind to this fact. He uses the information, however, in a different way from the man who taps the barometer in his hall to see whether it has gone up or down before leaving for business in the morning, a way that will be described later. He could, of course, obtain some idea whether the barometer is rising or falling by comparing the reading received from a station with that received at the last hour of observation. This would not be entirely satisfactory. What is really desired is to know whether the barometer is rising or falling at the time, and for this reason self-recording barometers

* With the addition of the appropriate symbol to indicate passing showers of rain, snow or sleet.

(barographs) are supplied to all observing stations, and the observer is instructed to report the amount by which pressure has changed in the three hours preceding the time of observation and whether the change has been going on steadily during this period or otherwise. The amount of the rise or fall is called the "barometric tendency" or more commonly just the "tendency." The form of the change, whether there has been a continuous rise during the three hours, a fall at first followed by a rise later, or other type of change, is known as the "characteristic" and is also reported. These readings are entered on the weather map and, in the Meteorological Office, in order to bring out clearly the regions where pressure is rising, the tendency figure when positive is entered in black. Negative tendencies are in red. Lines can be drawn through places having the same barometric tendency in the same way that they are drawn through places having the same barometric pressure. Such lines are called isallobars. Isallobars indicate clearly both the regions where the barometer is rising and falling and the intensity of the rise and fall.

Barometric tendency completes the list of readings which were telegraphed to the Meteorological Office before the war, and we now come to certain further observations which war-time developments showed to be of importance for forecasting. Of these the primary one was a detailed report of cloud. Formerly an indication of the degree of cloudiness of the sky was given by use of the Beaufort letters b—blue sky, bc—mixed blue sky and cloud, c—cloudy and o—overcast, but no indication was given of the type of cloud or when more than one type was present of the individual amounts of the separate types. Certain forms of cloud are of great importance in forecasting, for example, a thin sheet of high cloud spreading across the sky from the west often forms one of the earliest indications of a coming depression. Clouds of the heaped-up type known as cumulus, when well developed are indicative of what is called instability in the air, a condition which is associated with showers and sometimes with thunderstorms. Several different methods of classifying clouds have been put forward by meteorologists. The one in general use at the present time is that recommended by the International Meteorological Committee, a body of meteorologists representative of the official services of nearly all countries. A new " International Atlas of Clouds and of States of the Sky " was issued by this Committee in 1932 and the definitions and descriptions of the different cloud types given below are taken from this Atlas.

International Definitions and Descriptions of Cloud Forms

1. **Cirrus (Ci).—Detached clouds of delicate and fibrous appearance, without shading, generally white in colour, often of a silky appearance.**

Cirrus appears in **the most varied forms** such as isolated tufts, lines drawn across a blue sky, branching feather-like plumes, curved lines ending in tufts, etc.; they are often arranged in bands which cross the sky like meridian lines, and which, owing to the effect of perspective, converge to a point on the horizon, or to two opposite points (cirrostratus and cirrocumulus often take part in the formation of these bands).

2. **Cirrocumulus (Cc).—A cirriform layer or patch composed of small white flakes or of very small globular masses, without shadows, which are arranged in groups or lines, or more often in ripples resembling those of the sand on the sea shore.**

In general cirrocumulus represents a degraded state of cirrus and cirrostratus both of which may change into it. In this case the changing patches often retain some fibrous structure in places.

Real cirrocumulus is uncommon. It must not be confused with small altocumulus patches on the edges of altocumulus sheets.

3. **Cirrostratus (Cs).—A thin whitish veil, which does not blur the outlines of the sun or moon, but gives rise to halos.** Sometimes it is quite diffuse and merely gives the sky a milky look ; sometimes it more or less distinctly shows a fibrous structure with disordered filaments.

4. **Altocumulus (Ac).—A layer, or patches composed of laminae or rather flattened globular masses, the smallest elements of the regularly arranged layer being fairly small and thin, with or without shading.** These elements are arranged in groups, in lines or waves, following one or two directions and are sometimes so close together that their edges join.

The thin and semi-transparent edges of the elements often show **irisations** which are rather characteristic of this class of cloud.

5. **Altostratus (As).—Striated or fibrous veil, more or less grey or bluish in colour.**—This cloud is like thick cirrostratus but without halo phenomena ; the sun or moon shows vaguely, with a faint gleam, as though through ground glass. Sometimes the sheet is thin with forms intermediate with cirrostratus (altostratus translucidus). Sometimes it is very thick and dark (altostratus opacus), sometimes even completely hiding the sun or moon. In this case differences of thickness may cause relatively light patches between very dark parts ; but the surface never shows real relief, and the striated or fibrous structure is always seen in places in the body of the cloud.

6. **Stratocumulus (Sc).—A layer or patches composed of laminae or globular masses ; the smallest of the regularly arranged elements are fairly large ; they are soft and grey, with darker parts.**—These elements are arranged in groups, in lines, or in waves, aligned in one or in two directions. Very often the rolls are so close that their edges join together ; when they cover the whole sky, as on the continent, especially in winter, they have a wavy appearance.

7. **Stratus (St).—A uniform layer of cloud, resembling fog, but not resting on the ground.**—When this very low layer is broken up into irregular shreads it is designated fractostratus (Fs).

8. **Nimbostratus (Ns).—A low, amorphous, and rainy layer, of a dark grey colour and nearly uniform ;** feebly illuminated seemingly from inside. When it gives precipitation it is in the form of continuous rain or snow.

But precipitation alone is not a sufficient criterion to distinguish the cloud which should be called nimbostratus even when no rain or snow falls from it.

There is often precipitation which does not reach the ground ; in this case the base of the cloud is always diffuse and looks " wet " on account of the general trailing precipitation, **virga,** so that it is not possible to determine the limit of its lower surface.

9. **Cumulus (Cu).—Thick clouds with vertical development ; the upper surface is dome-shaped and exhibits protuberances while the base is nearly horizontal.**

When the cloud is opposite to the sun the surfaces normal to the observer are brighter than the edges of the protuberances. When the light comes from the side, the clouds exhibit strong contrasts of light and shade ; against the sun, on the other hand, they look dark with a bright edge.

True cumulus is definitely limited above and below, its surface often appears hard and clear cut. But one may also observe a cloud resembling ragged cumulus in which the different parts show constant change. This cloud is designated fractocumulus (Fc).

10. **Cumulonimbus (Cb).—Heavy masses of cloud, with great vertical development, whose cumuliform summits rise in the form of mountains or towers, the upper parts having a fibrous texture and often spreading out in the shape of an anvil.**

The base resembles nimbostratus, and one generally notices **virga.** This base has often a layer of very low ragged clouds below it (fractostratus, fractocumulus).

Cumulonimbus clouds generally produce showers of rain or snow and sometimes of hail or soft hail, and often thunderstorms as well.

If the whole of the cloud cannot be seen the fall of a real shower is enough to characterise the cloud as a cumulonimbus.

It is not proposed to discuss these cloud types in detail. They may be divided into three main groups.

(1) High clouds consisting of cirrus, cirrostratus and cirrocumulus; the clouds of thin texture which generally occur at a height of about 25,000 ft. or 5 miles.

(2) Medium clouds. Altostratus and altocumulus which are somewhat similar in appearance to cirrostratus and cirrocumulus but are denser and occur at a lower level.

(3) Clouds of which the base at least is at a low level though in some cases the summits tower to a great height. These low clouds may be sub-divided into two classes: stratified clouds which form a sheet often covering the whole sky and sometimes of great thickness. These at times give rain and at other times persistent dull and depressing weather though without actual rain. The other class consists of heap or cumulus clouds. These frequently form on fine summer days and, reaching no great size, cause no interruption of the fine weather. On other occasions they tower up to great heights and lead to heavy showers and thunderstorms.

Cumulus clouds are the most impressive of all cloud forms, and when the sun shines on them show a brilliantly lighted face which is often set off by dark shadows over the parts hidden from the sun. Some of the most beautiful forms are, however, found in cloud of the cirrus type, the structure of which is very delicate.

Symbols showing the type of high cloud, medium cloud and low cloud, together with the amount and height of the base of the low cloud, present at a station are entered on the weather map at Headquarters and give the forecaster the information which he requires regarding the appearance of the sky. The direction and speed of movement of high clouds are also reported whenever possible; they give valuable information regarding the wind currents at high levels. An instrument named a nephoscope is used for this observation. It gives the apparent or angular speed of movement, and to deduce the actual speed in miles per hour it is necessary to know the height of the cloud. An average height is taken for each type of cloud for this purpose; thus cirrus clouds are assumed to be at a height of 5 miles, altostratus and altocumulus at a height of 3 miles.

When discussing temperature it was pointed out that this might be used as an indication of the source of the air, whether polar or equatorial, though care is necessary in interpreting the readings. Another element which is of use in this connexion is the relative humidity or dampness of the air. This

is included in meteorological reports. It is obtained from the readings of a pair of thermometers in the Stevenson screen, one of which has its bulb surrounded by muslin that is maintained damp by a wick leading from a small jar of water. The bulb of the other remains dry. The evaporation from the damp surface when the air is dry cools the one bulb, and the difference between the readings of the wet-bulb and dry-bulb thermometers indicates the relative humidity. Tables are used for the actual computation and one figure in the coded message is reserved for this report.

Another element which came into prominence during the war was visibility on account of its importance to aviators. Before the war visibility was only reported when it was either so bad that the term " fog " was appropriate or so good that distant objects stood out with unusual clearness. Cases where the obscurity was not quite bad enough to be reported as fog but might be termed " mist " were also sometimes mentioned in the reports. This information was quite insufficient for aviation and a visibility scale of 10 points was drawn up, the criteria being the distances at which well-marked objects can be distinguished. Thus if such objects are not visible beyond 55 yards the visibility is reported as 0. If they can be picked out at distances not exceeding 220 yards it is reported as 1 and so on, the scale running up to 9 which indicates conditions when objects are visible beyond 31 miles. Reports of visibility are of somewhat specialized use. The elements which have been dealt with previously are all now regarded as essential for the preparation of forecasts. Visibility is in a somewhat different category. There are times when it is helpful in diagnosing the weather situation but as a rule it may be regarded as essential only for particular types of forecast such as those for aviation.

This completes the list of observations normally entered on a weather map. Certain other information is telegraphed to forecasting centres, in particular the amount of rain which has fallen during the day and during the night, the amount of sunshine, the highest temperature which has occurred in the daytime and the lowest in the night with the lowest reading recorded by a thermometer freely exposed to the sky and lying over short grass. These readings, however, are not reported at all hours of observation and cannot be regarded as forming an essential part of a weather map.

The information which has been detailed above as of importance in forecasting occupies a good deal of space when entered on the map, even though the customary symbols are used for weather and clouds. It is found in the Meteorological Office that it is necessary to employ a map on a scale 1 : 5,000,000 for the purpose. On this scale the British Isles, from Land's End to John o' Groats, extend over about 8 in. A small section of one of these maps showing the actual scale employed is given in Fig. 8. The method of entering the observations is shown by the explanations appended to the readings for Cranwell in Lincolnshire. Certain of the entries are made in red ink as an aid to the eye in distinguishing between the different items but in the reproduction in Fig. 8 it has been possible to use black ink only. The word " red " in brackets indicates which entries are marked in red on the charts. It would not be practicable to use maps of this scale for a large area and the working charts of the Forecast Division which extend from Greenland in the north-west and the Azores in the south-west to Russia and Palestine in the east, are on half this scale, that is 1 : 10,000,000. On a chart of this size only certain of the observations can be entered against each station. Actually wind, barometric pressure and tendency, weather and temperature, are shown. Even this scale is too large for convenience of manipulation when plotting observations over a region comprising most of the northern hemisphere. In the published charts of the Meteorological Office for this area, one of which was shown in Fig. 3 facing p. 7, a scale of 1 : 40,000,000 is employed, the British Isles on this scale measuring 1 inch from Cornwall to the north of Scotland.

It is not necessary on a chart covering this area to show the details of the weather in every district, what is desired rather is to give a general view of the conditions over the whole. An open network of stations is therefore used and only wind, weather and temperature are entered for each station, pressure being shown by the isobars but not by entry of individual station readings.

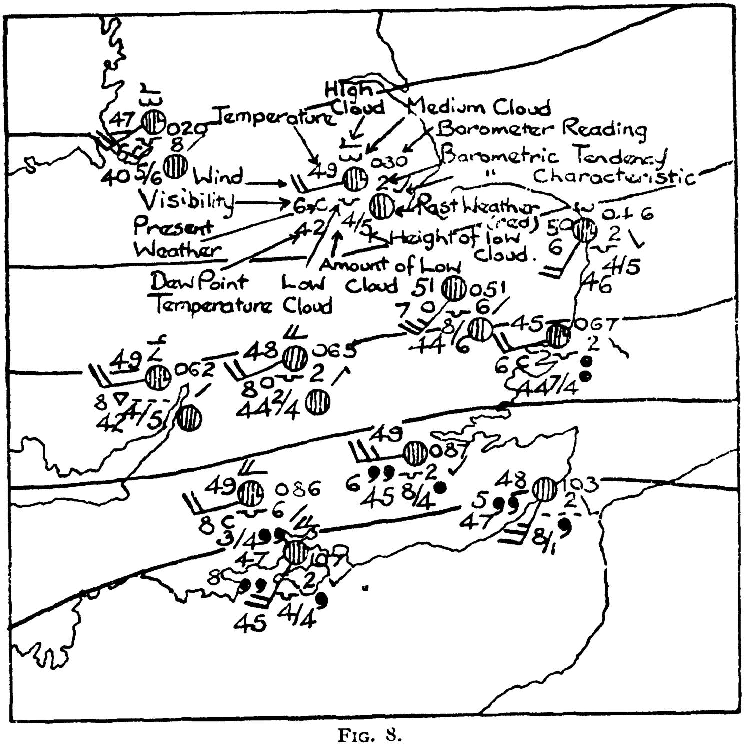


FIG. 8.

For special purposes maps of a much larger scale than any of those mentioned above may be used.

The maps which will be reproduced in the later chapters of this book to illustrate various types of weather will be on a uniform plan and on a scale of 1 : 20,000,000. For the sake of clearness only a selection of the information which is received in the Meteorological Office will be entered on them. This will consist of wind, temperature and weather for about 15 stations in the British Isles and 35 in neighbouring countries and for a few ships on the Atlantic Ocean. The weather is indicated by Beaufort letters and the symbols shown on p. 25 are not used. Pressure will be shown by isobars drawn for 4 mb. intervals, and the warm and cold fronts and occlusions (see Chapter V) marked in. The map of which certain features have been shown separately in Figs. 4 and 7 (pp. 11 and 24) is given in the standard form in Fig. 9 at the beginning of the next chapter. This form is similar to that adopted by *The Times* and *The Daily Telegraph* newspapers in England, and by the *Scotsman* and *Glasgow Herald* in Scotland, in the maps which they published daily before the 1939-45 war, but which have not yet been resumed.

at any point on the way. On the other hand it may happen that the wind at Newcastle and at Hull is blowing from the same direction as at Aberdeen, that is from the E.; while at a point just south of Hull the wind is from the S. and blows from the same direction at Yarmouth and London. There will then be a sudden change of wind in the neighbourhood of Hull, and two places only a few miles apart may have the one a wind from the E. and the other a wind from the S. This is called a discontinuous change, and the line which separates places having an E. wind from those having a S. wind is called a line of discontinuity. The example given has referred to wind but changes of other elements may also be continuous or discontinuous. This is particularly true of temperature. Cases are found on weather maps where the temperature at all places on one side of a certain line drawn across the map is markedly higher than that at places on the other side. The older meteorologists recognised that there were sometimes lines of discontinuity of wind and temperature along the trough line of a depression. Temperature was lower behind the line than in front and the wind veered there, that is changed in a clockwise manner as from SW. to NW., but they were apt to regard such discontinuities as an incidental part of the depression and not as playing any fundamental part in its structure.

During the war the Norwegian meteorologists, being almost entirely cut off from foreign reports, developed a very close network of observing stations in their own country at which accurate readings were taken at frequent intervals and transmitted to headquarters. Study of these detailed readings showed that discontinuities occurred more often than had been suspected, and led to the development of the theory of formation of depressions known as the "polar front" theory which has since met with wide acceptance. This theory was worked out on its mathematical side by Professor V. Bjerknes and developed with great practical ingenuity by his son Dr. J. Bjerknes. The theory demands that depressions should be formed only in regions where masses of air of widely different characteristics are brought into close contact. These masses are termed for convenience "polar" and "tropical" as they normally come from polar and tropical regions respectively. Polar air is cold, dry and frequently associated with clear or partially clear skies; tropical air is warm, moist and contains much cloud. Before a depression develops these two air masses are flowing in parallel streams but in opposite directions like two trains passing one another on the up and down lines of a railway. The cold polar air flows from the NE. towards the SW. on the northern side of the line of separation while the equatorial air flows from SW. to NE. on the southern side. These streams are shown diagrammatically in Fig. 11 (p. 35). The line of separation is a line of discontinuity with widely differing conditions on its two sides. It is termed the "polar front." The surface of separation between the warm air and the cold air does not stand vertically above the polar front like a wall or partition but rises with a very gentle slope to the northward so that one hundred miles north of the front the warm tropical air will be found above the surface of separation at about one mile above the earth.

Sometimes the polar air flows from west or even south-west after curving round an old depression to northwards. In this case also there is a surface of discontinuity between the polar and tropical air. An example of this type of front is given in Fig. 11 (b). It may be noticed that although in this case the direction of the two currents is the same, the cold current has the lower velocity, shown by shorter arrows, so that the relative motion of the two currents is the same as in Fig. 11 (a). It can be proved that at every front the relative motion is of this (i.e. cyclonic) type. The front need not be stationary, but it is found that a rapid motion is unfavourable for new developments. The warm air mass is also liable to follow a curved path and may move from north-west

or (in summer) from south-east or even east, but it generally moves from some point between south and west. The important point is the existence of a front with a sloping surface of discontinuity.

The conditions postulated are not really stable, and if the balance is disturbed a complete breakdown of stability may rapidly develop. The problem presented by the stability of a sloping surface of discontinuity in the atmosphere is so difficult that no satisfactory solution of it has yet been found, although a considerable amount of relevant upper air information is now available. All we shall attempt here is a brief description of the actual facts as they appear on sea-level weather charts. The birth of a depression coincides with the appearance of a slight bend in the previously straight front. Fig. 12 illustrates this stage, the two diagrams corresponding to the two cases in Fig. 11. Small incipient depressions of this type, which move along the front, are often called " waves " to which they bear a certain resemblance. Occasionally they die out as they move, but more often the development continues, until the stage shown in Fig. 13 is reached. Only one diagram is now necessary, since if the depression once reaches a sufficient degree of intensity, there must be an E. to NE. wind on the left-hand side of its track, even if such a current did not exist previously. The centre of the depression is the tip of the bulge or " warm sector " at the point marked C. The depression travels along the polar front in a north-easterly direction. Now warm air is lighter than cold air. A homely illustration of this is afforded by the ordinary domestic fire in which the smoke goes up the chimney without needing any fan to drive it. Smoky air is actually slightly heavier than clear air, and if the smoky air in the chimney were cold, it would come down the chimney into the room and not go up into the atmosphere. It is solely the fact that the smoky air is warm which makes it rise. The air then within the bulge of the polar front which is warm is lighter than the air on the north side of the bulge which is cold, and where the two converge the warm air rises over the cold or the cold air cuts under the warm.

A fuller explanation of the ascent of air must take into account not only the temperature of the air but also the convergence in its motion (see p. 44) which is the inevitable accompaniment of the development and motion of the disturbance.

If Fig. 13 is examined it will be seen that along the part of the polar front marked CD the warm air is blowing against the side of the cold stream and will therefore rise over it ; along that part of the front marked BC the cold heavy air is, so to speak, driving a wedge under the warm air. CD is called the " warm front," BC the " cold front " while the area between these two is known as the " warm sector " of the depression. These features are shown more clearly in Fig. 15 (p. 37). In the lower part of Fig. 13 there is given a vertical section of the conditions prevailing above the dotted line marked UX in the upper part of the figure. This vertical section shows the conditions which would be found by an observer were he able to move about freely on a vertical scaffolding erected on the line UX. Along the ground he would find cold air from U to V, warm from V to W and cold again from W to X. Above the region UV there is a wedge of cold air sloping backwards from V and above WX another wedge of cold air sloping forward from W. The movement of the air is again shown by the arrows, and it will be seen that the warm air above the front wedge of cold air has a distinct upward movement in addition to its horizontal velocity. Now we shall see that this, or indeed any, upward movement in the air is of the greatest importance. It was shown in an earlier chapter that the pressure in the atmosphere decreases rapidly with increase of height so that the air in this upward stream is constantly reaching regions where pressure is lower. The air accordingly expands in just the same way as

the gas in a balloon or airship expands and has to be released as the ship rises in the atmosphere. It is a physical fact of the utmost importance in meteorology that air which expands becomes colder so that this rising air, if dry, loses between 5° and 6° of temperature for every 1,000 ft. through which it rises. Moist air loses temperature at a smaller rate but even in this case the loss is some 3° per 1,000 ft. If the air were dry this loss of temperature though large would not be a matter of great importance, but it has been mentioned that equatorial air is generally damp and the cooling is accompanied by condensation of the water vapour from its invisible form to the minute visible drops of water which form a cloud. As the rising continues the cloud becomes denser, and when the waterdrops can no longer be maintained in the air they commence to fall as rain.

Fig. 11

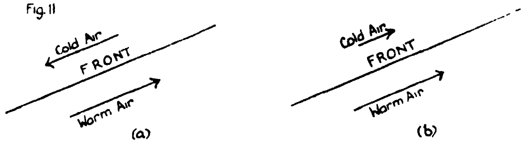


Fig 12

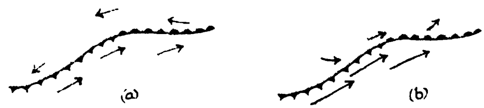


Fig 13

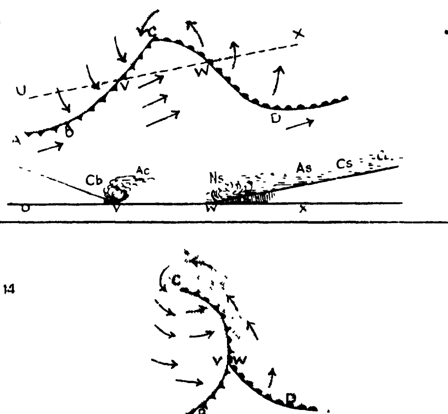
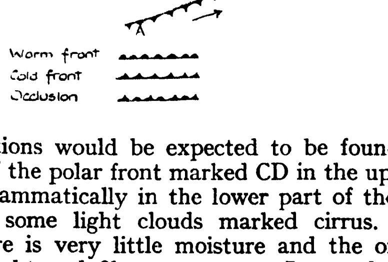


Fig 14



These conditions would be expected to be found then to the north-east of the portion of the polar front marked CD in the upper part of Fig. 13. They are shown diagrammatically in the lower part of the figure. In the extreme front we have some light clouds marked cirrus. At this height in the atmosphere there is very little moisture and the only clouds which can be formed are of light and fibrous texture. Lower down we have cirrostratus,

the type of cloud in which halos are formed, and then altostratus, a uniform sheet of high cloud which becomes thick enough to blot out the sun entirely. Behind this again comes the nimbostratus or rain cloud from which rain is seen to be falling. The surface of the front slopes up at such a slight angle that the distance between the advanced part where cirrus is formed and the point where the front strikes the ground generally amounts to hundreds of miles. It is important to notice that over the region WX although there is polar air near the ground if an ascent is made to some height, equatorial air will be encountered. In the central region VW conditions are different for here tropical air is found both at the surface and in the upper regions. The weather, therefore, in this part partakes of that appropriate to tropical air. It is damp, warm and cloudy but rain does not usually fall, at any rate not in large quantities. Behind we have conditions which at first sight appear not dissimilar to those prevailing in front of W, that is we have polar air on the ground with equatorial air above it but here the polar air is pushing wedgewise under the equatorial air and the surface of separation is much steeper than that in front of W. The result is that in this region the rain falls in the form of a short but heavy shower of quite a different character from the prolonged rain in front. When the heavy shower has passed the weather rapidly takes the form appropriate to polar air with clear skies broken by occasional cumulus clouds and showers. Remarkably good visibility of distant objects is often another attribute. The regions where rain is falling are shown on these diagrams as stippled areas.

It will be of interest at this stage to compare the weather which has been deduced on theoretical grounds as appropriate to a depression of the Bjerknes type, with the weather regarded by Abercromby as normal to depressions from his long experience. We must remember that the Bjerknes depression passes from left to right along the original line of the polar front carrying its weather with it. Passing from the front to the rear of the depression the high cirrus clouds with a halo round the sun, the watery sky associated with altostratus cloud followed by nimbus and rain are identical in the two systems, but when we come to the point W on the diagram, Fig. 13, we find a difference. Abercromby passes straight from the continuous rain to the clearing shower followed by bright skies and cooler air. Bjerknes interposes the region VW of warm cloudy air without heavy rain. Behind the point V the two descriptions of the weather again agree in every particular. The theory of Bjerknes agrees then with the facts of Abercromby in a remarkable manner. The one point of divergence will be explained later.

We will now return to the life history of the Bjerknes depression. We have seen that in the upper part of Fig. 13 the cold air is undercutting the warmer air along BC and the warm air is climbing over the cold along CD. The region in which warm air lies upon the ground will therefore be shrinking rapidly, and the two lines BC and CD will draw closer and closer together. The next stage of development is shown in Fig. 14 where the points V and W have come together, the warmer air having been pushed bodily off the ground along the region between C and VW. The depression is then said to be "occluded." No warm air will be found near its centre at C, but only in its outer parts. The line along which the warm air left the ground is called the "line of occlusion". It is important to notice that although there is after this stage no warm air left on the ground in the central regions, it will still be present in the upper atmosphere, having only been lifted up through a certain distance. The base of the operations will have been transferred from the ground to the upper atmosphere but the operations themselves will continue, though with gradually diminishing intensity. Rain and cloud will still be seen in front of CV, and the sharp shower associated with the passage of the cold front will

occur as the line CV, which is now coincident with CW passes. We have in fact the same weather sequence as in Fig. 13 except that the region of equatorial air VW with its associated weather has been removed; that is, we have precisely the weather conditions described by Abercromby whose description fits not only in general but even in detail with the weather conditions found in an occluded depression of Bjerknes.

Now depressions when they reach the British Isles are nearly always occluded, and Abercromby's generalisation may well have been based primarily on such. They form as a rule far out on the Atlantic, and while the warm sector between BC and CD in Fig. 13 persists, increase rapidly in intensity, it being a rule of Bjerknes that depressions while they retain a warm sector remain in the stage of growth. But this very increase of intensity with strengthening winds leads to the rapid undercutting of the warm sector and occlusion of the depression, and it is seldom that by the time the British Isles are reached any warm sector is found on the earth's surface. This fact also makes it difficult to identify the features which Bjerknes regards as forming a fundamental part of a depression from surface observations when the depression is centred over the British Isles. If readings of temperature and wind were readily available at some height above the surface the cold and warm sectors might more easily be traced, but from surface observations all that we can go upon is the region of cloud and rain with perhaps some faint contrast of temperature between the air in front of the occlusion CD and that behind it. The air on both sides will be of polar origin, but as the two air masses may have travelled over widely different paths since leaving polar regions, the temperature on the two sides will not necessarily be the same.

It will be noticed that in the account which has been given of the structure of a depression in accordance with the Bjerknes theory, no mention has been made of barometric pressure or isobars. In this the practice of the Norwegian meteorologists has been followed. In working out their theory they concentrated attention almost entirely on the flow of air and regarded the pressure distribution as a matter of minor importance. In their diagrams they showed

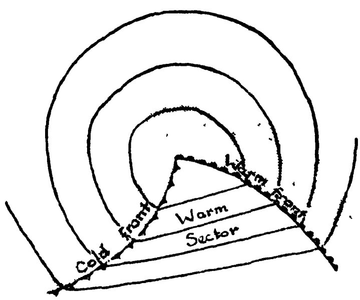


FIG. 15.—Depression after Bjerknes, showing isobars

wind arrows rather than isobars and this method has been followed in the preceding description. We cannot however afford to neglect isobars altogether, and it is necessary to consider their relation to the " fronts " and wind arrows shown in Fig. 13. It has been explained that the point C at the top of the warm sector marks the centre of the depression or the region where the barometer is lowest. The isobars form closed curves round this point but they do not, according to Bjerknes, run smoothly as in the older representations but form angles where they cross the cold front BC and the warm front CD, that

is the lines along which there are discontinuities of wind and temperature. There cannot in the atmosphere be an actual discontinuity of pressure but an angle or sharp bend in the isobars is not impossible. Fig. 15 is a reproduction of the essential parts of Fig. 13 with the isobars added. Opportunity has also been taken in this diagram to name the salient features of a depression in the light of the Bjerknes theory, the warm and cold sectors and the warm and cold fronts. The method of indicating fronts on the diagrams and charts is the standard one when colours cannot be used. On working charts warm fronts are marked in red, cold fronts in blue and occlusions in purple.

It may be asked why isobars should continue to be shown as smooth curves on weather maps if actually they contain sharp angles. The answer to this is that the angles are only found in growing depressions which have well-marked warm sectors and it has been pointed out that depressions when they reach the British Isles rarely have this feature. When the depression becomes occluded the angles become smoothed out and in many cases the precise position of the line of occlusion on the chart is difficult to locate.

It will be of interest to illustrate a depression which crossed the British Isles at the time when this chapter was being written and showed a well marked line of discontinuity. This occurred on the morning of October 11, 1928, and is illustrated in Fig. 16 (facing p. 33). A depression of elongated shape was situated over the Atlantic off the west of Ireland, and the wind was easterly over Scotland but westerly over the south-west of England. A line has been drawn on the map passing across the north of Ireland and the Irish Sea and then crossing England almost in a straight line from Chester to the neighbourhood of the Isle of Wight. The wind on the east of this line is blowing from the E. or SE. while at every place on the west of the line a westerly wind current prevails. There appears to be a true discontinuity of wind along the line. If the temperatures are examined it will be seen that there is also a discontinuity of temperature, readings on the west of the line being several degrees higher than those on the east. This was a case when the warm air was rising over the cold air and partook of the nature of a warm front.

The sequence of weather as the front passed over the meteorological station at Holyhead is shown by the reproduction of autographic records in Fig. 17. The curves show the changes in wind velocity and direction, in temperature and pressure, with the rainfall from midnight to noon on October 11. The hours are marked at the top of the sheet, and the method of interpreting the curves will be plain if it is realised that they show the changes of wind, temperature and pressure in just the same way as the record of an ordinary barograph shows pressure changes. Thus the pressure curve at the bottom of the diagram is a barograph curve. It shows that the barometer fell from 1004 mb. at midnight to a minimum of 996 mb. between 6 h. and 7 h., after which it rose steadily. Temperature is indicated in the same manner, a scale of degrees Fahrenheit being entered on the left hand side of the diagram. The wind records show the rapid fluctuations both in the velocity and direction, that is the gustiness, which has already been referred to as forming a normal feature of wind structure. A word of explanation is necessary with regard to the rainfall diagram. Rainfall is measured in millimetres at official meteorological stations and a scale of millimetres is given at the side of the diagram. It will be noticed that the record rises from 0 mm. to 10 mm. and then drops sharply to the 0 mm. line again. It is necessary to arrange for the pen of a self-recording rain-gauge to return to the bottom of the trace when it reaches the top in order that the record may not be lost. In order to obtain a clear picture of the rainfall this drop should be regarded as non-existent, the second part of the trace being raised through 10 mm. and joined on to the first.

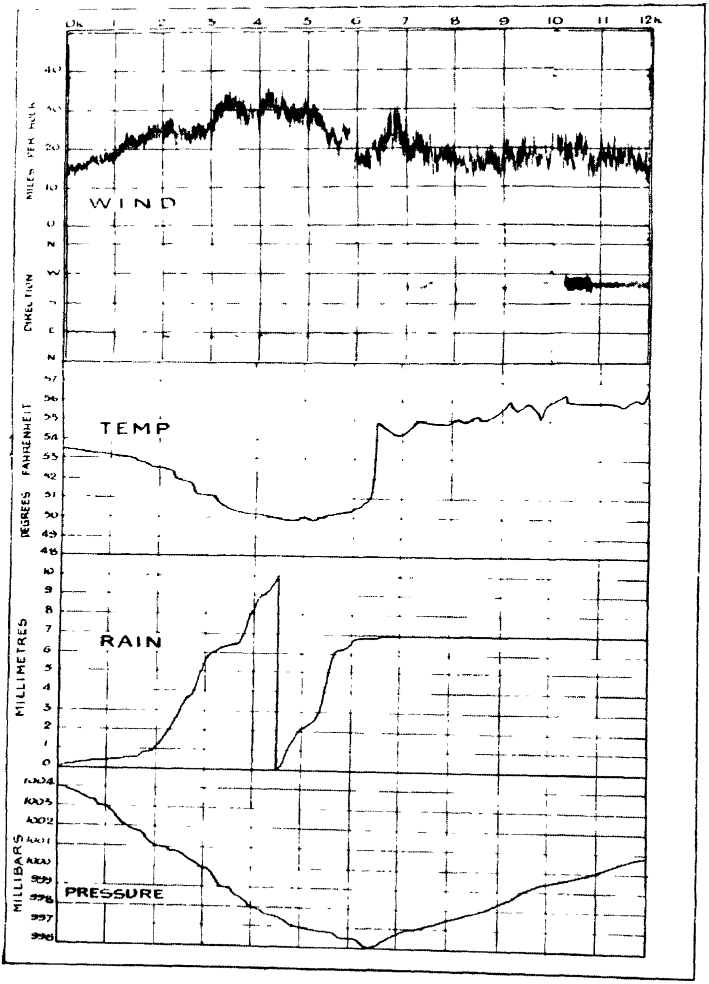
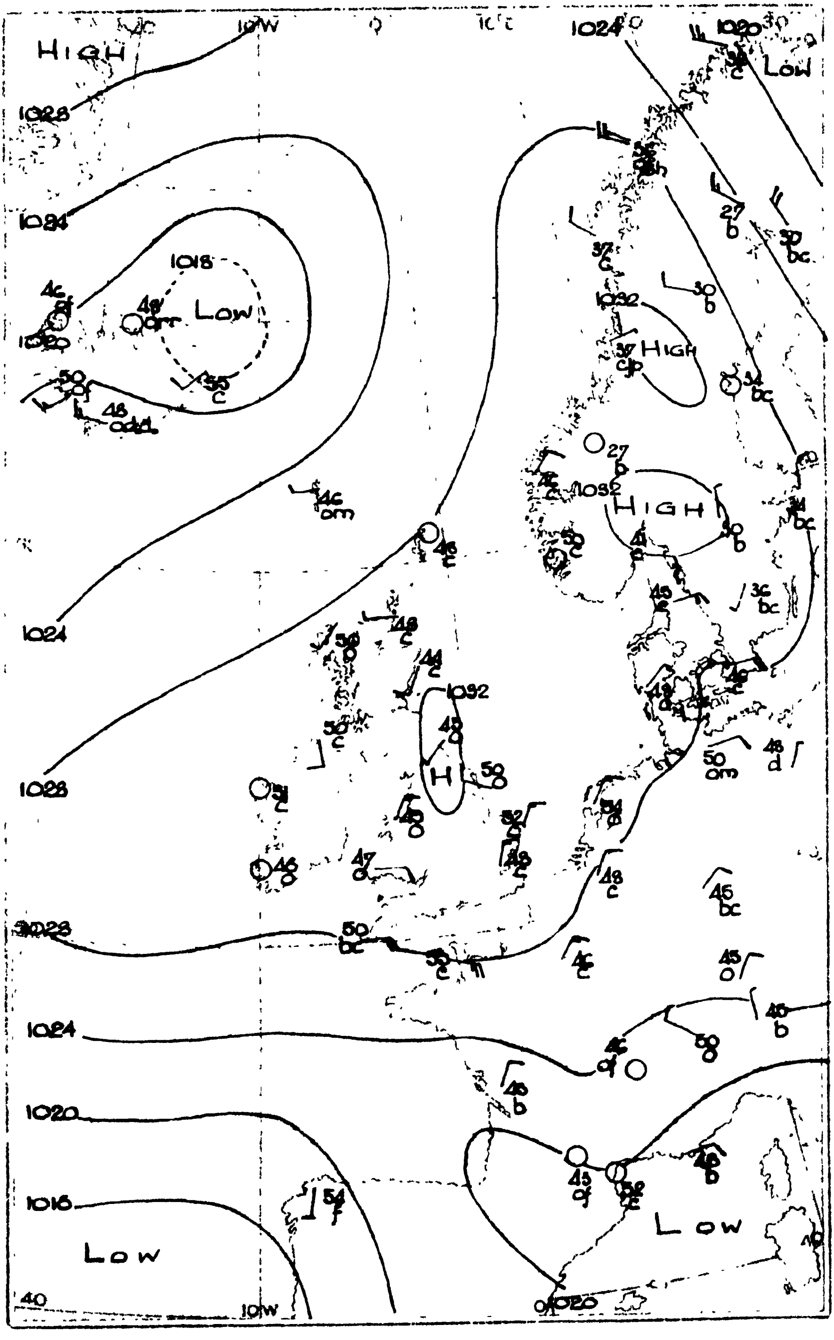


FIG 17.—October 11, 1928 Holyhead



OCTOBER 12, 1927, 7h.

The sudden change in the weather as the front passed Holyhead is clearly shown by these curves and is in good agreement with that which would be expected from the features of the map shown in Fig. 16. The wind which had been E. turned sharply to the SW. just before 6 h. 30 m. At the same time temperature rose from 51° to 55° and the rain which had persisted for many hours ceased. The rainfall therefore occurred in the manner appropriate to a warm front on the Bjerknes theory.

Although this front partook in most respects of the nature of a warm front it was in real truth an " occlusion ", the air behind the front not being true tropical air but polar air which had become warmed by travelling a long distance over the warm waters of the Atlantic. This explains the fact that the weather behind the front was bright, with a tendency for showers, and not cloudy, with occasional slight rain or drizzle, as in true tropical air.

CHAPTER VI

Weather associated with Pressure Systems—Anticyclones and Subsidiary Systems

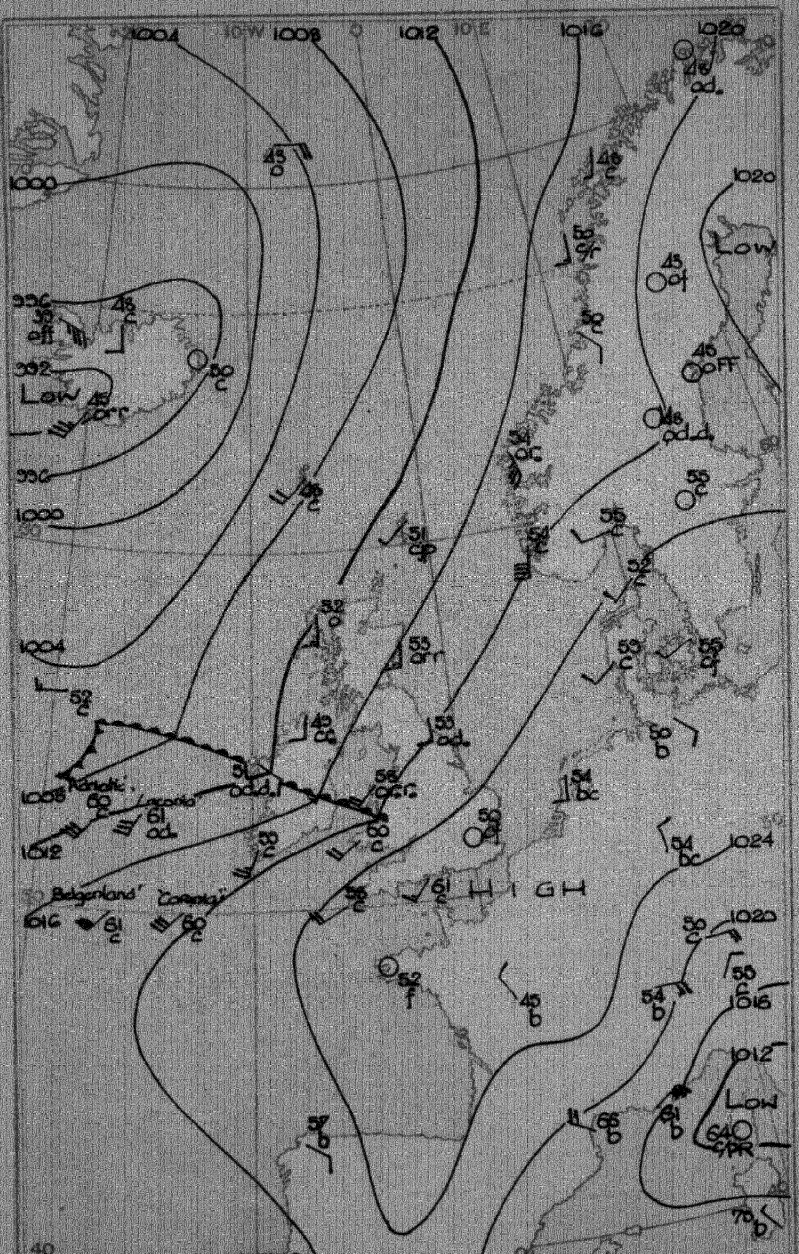
Anticyclones

The map chosen in Chapter II to illustrate the plotting of pressure and wind observations showed a depression, and the weather associated with these systems has been dealt with at some length in the preceding chapter. We will now pass on to other pressure types and will consider in turn the anticyclone, the secondary depression, the trough, the wedge and the col.

The anticyclone, sometimes called a " high ", is in most respects the opposite to the cyclone or depression. It is a region of high pressure round which the winds, for the most part light, circulate in a clockwise direction. In Fig. 18 pressure is above 1032 mb. over the north of England and exceeds 1030 mb. over the whole of the British Isles with the exception of the extreme north of Scotland and south of England. This area with an extension over the North Sea to Norway forms the central region of the anticyclone or " high ". Winds are light and variable in the centre, but blow from the W. or SW. in Scotland and from the E. or NE. in the English Channel in accordance with the " clockwise " rule. Anticyclones show little energy, and in Europe at least often remain in one spot for days or even weeks at a time. The weather associated with them is essentially quiet. Strong winds are never found in their central parts. This statement is not based on observation only but rests upon a secure theoretical foundation. It can be shown mathematically that where the isobars are curved round a high-pressure area in a curve of relatively small diameter the theoretical or " gradient " wind cannot exceed a moderate value. Since the relation between the wind calculated from the pressure gradient and the true wind is a close one it is not surprising to find that on weather maps strong winds are absent from the central regions of anticyclones.

Another characteristic of these systems is that rain seldom falls in a well-marked anticyclone. Drizzle may occur but rain is very unlikely. The reason for this will be explained later. This absence of rain is not necessarily associated with a clear sky. In this particular anticyclones fall into two distinct classes, cloudless anticyclones and overcast anticyclones. In the summer the first type is predominant. Brilliant sunny days frequently succeed one another without interruption so long as an anticyclone persists. Small clouds of the cumulus type may develop in the afternoon but they grow to no great size and fade away again in the evening. An anticyclone of the brilliant,

Fig. 20. To face page 41.



SEPTEMBER 17, 1928, 7 h.
<u>SECONDARY DEPRESSION</u> (WITH WARM SECTOR)

Shaw, a " lid ", owing to the fact that no vertical movement of air can take place through it, and this lid retains all the smoke and dust within the surface layers. Visibility is for this reason seldom good in an anticyclone. In some cases the smoke is carried up to the " lid " by rising currents and there permeates the cloud sheet forming a dense layer through which no daylight can penetrate. This is the high fog which is well known to Londoners and other dwellers in large cities when at street level the atmosphere is comparatively clear but day is turned into night. Anticyclones are not only favourable for the formation of this high fog but they are also frequently regions of dense surface fog. This is mainly due to the absence of wind, any wind serving to dissipate a land fog. When the ground cools at night moisture is condensed into visible water drops and fog is formed. This may happen at any time of the year but in the summer the heat from the sun when it rises is sufficient to evaporate the fog particles, and the fog, if it forms, is cleared off soon after daybreak. In winter the sun has little heat and even if no upper cloud sheet is present to cut off its rays, these rays strike the top surface of the fog at such a low angle that they have little power to dissipate it.

From what has been said it will be seen that a winter anticyclone is frequently a region of dull skies and of fogs. In these circumstances it is somewhat curious that anticyclones should generally be regarded as productive of good weather. Their good reputation in this respect is founded upon their summer characteristics and upon the absence of rain which is associated with them at all times of the year. The unpleasant features of anticyclonic weather in the winter are often overlooked.

Secondary Depressions

Secondary depressions, frequently termed " secondaries ", are low-pressure systems contained within a parent depression. They may vary in intensity from a slight sinuosity in the isobars to a system which itself contains closed isobars with a steep pressure gradient and destructive winds. Secondaries of every intermediate intensity also occur. The two extremes are illustrated in Figs. 20 and 21. In Fig. 20 a slight deflection of the isobars will be noticed over north-west Ireland which indicates the secondary, while in Fig. 21 the secondary over the south of England cannot fail to be seen, it being a more prominent feature on the map than the parent depression. Secondaries may form in any part of the main depression, but they seem to reach their greatest development on the southern side. They cause an increase in the strength of the wind on the side remote from the main " low ", that is as a rule on their southern side, and a decrease on the side towards the low. With an intense secondary the winds on the northern side are not weak from the W., but are reversed in direction so that they may be strong or occasionally reach gale force from the E. although the general system of winds in that part of the main depression would lead to a westerly current. The secondary in this case has a complete wind circulation of its own independent of the primary. The easterly winds on the northern side are, however, less strong than the westerly winds on the southern side and whereas gales are frequent in the latter region they are rather rare in the former. Some of the strongest winds which are experienced in the south of the British Isles are associated with secondaries. That shown in Fig. 21 gave a gust at Pendennis Castle near Falmouth of 103 m.p.h. This does not mean that winds in a secondary are necessarily stronger than those in a primary, but that intense primary depressions generally pass from the Atlantic along the north-western seaboard of the British Isles so that the south of England is at some distance from their central regions. The strongest winds associated with the primary are therefore experienced in Ireland and Scotland and not in the south. Secondaries to these depressions

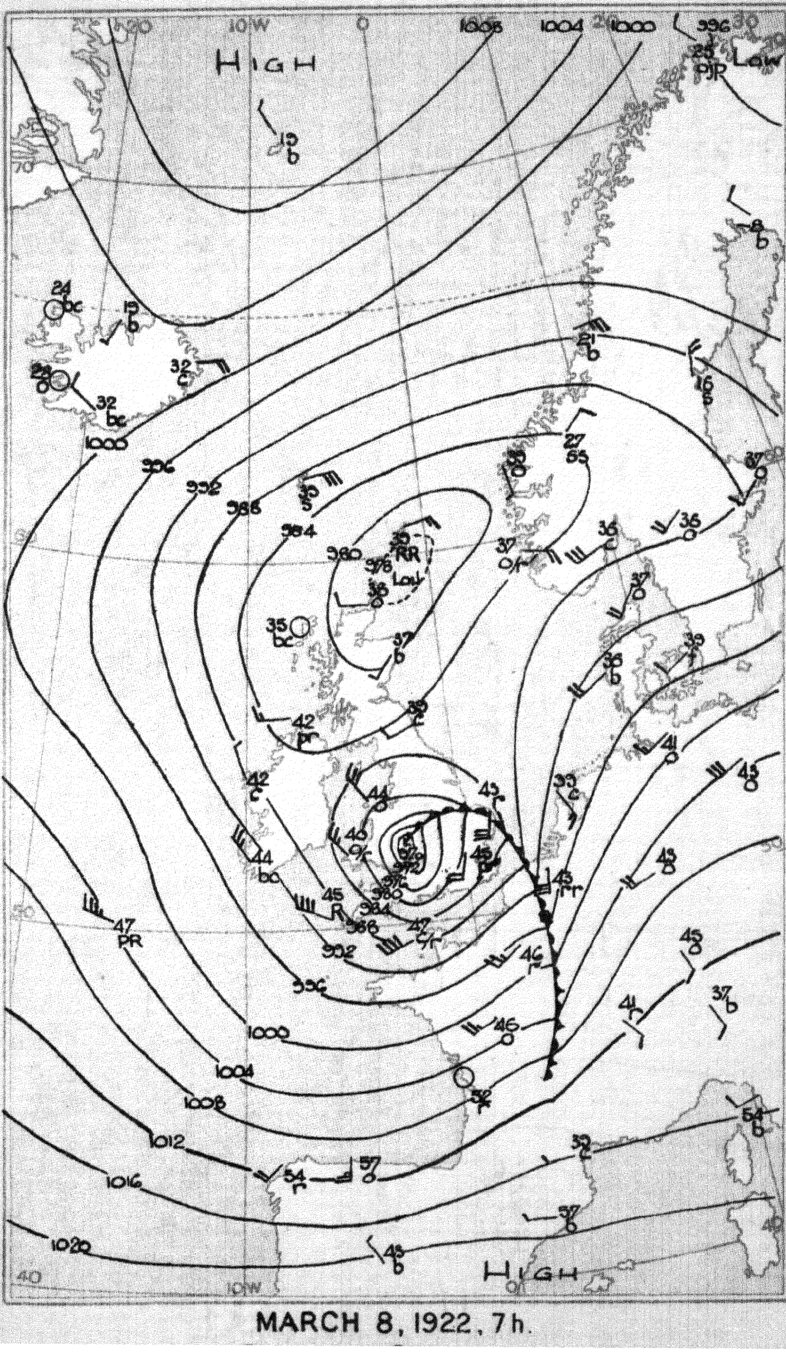
often pass to the south of Ireland and travel up the English Channel or across the south of the country from west to east. The southerly gales in front of them and westerly gales on the southern side frequently attain very high velocities, and a winter seldom passes without damage to buildings and to shipping from this cause.

With regard to weather, well developed secondaries have most of the attributes of a primary and may have warm and cold fronts giving clouds and rain. The weather is more consistently bad than that associated with primary depressions. Whereas the former sometimes pass a district without appreciable rain falling, a well-marked secondary seems hardly ever to do so. Even the feeble systems which are indicated by small sinuosities in the isobars as in Fig. 20 are found to be regions of cloud and frequently of rain so that a forecaster soon learns to pay careful heed to any signs of the development of a secondary. The movement of these systems is generally one of rotation round the parent system as a centre in a counter-clockwise direction to which is added the movement of the parent depression itself. The speed at which they travel seems to be governed to some extent by steepness of the pressure gradient associated with the main depression in the region in which they are formed. If the pressure gradient is steep they travel more quickly than if it is slight. There appears in some cases to be an even more intimate association between their speed and that of the winds prevailing at high levels in front of their advance. When clouds of cirrus type which form at a height of some five miles above the earth's surface are moving rapidly from the west in front of a secondary, it may be taken as an indication that the secondary will travel more quickly than if the cirrus is only moving at a slow speed. Secondary depressions are the most frequent of any pressure type. It is seldom that a primary depression exists for long without the formation of a secondary, and a sequence of these may follow one another, moving in a counter-clockwise direction round the primary, with so little interval that the effect of one has hardly passed before another is felt.

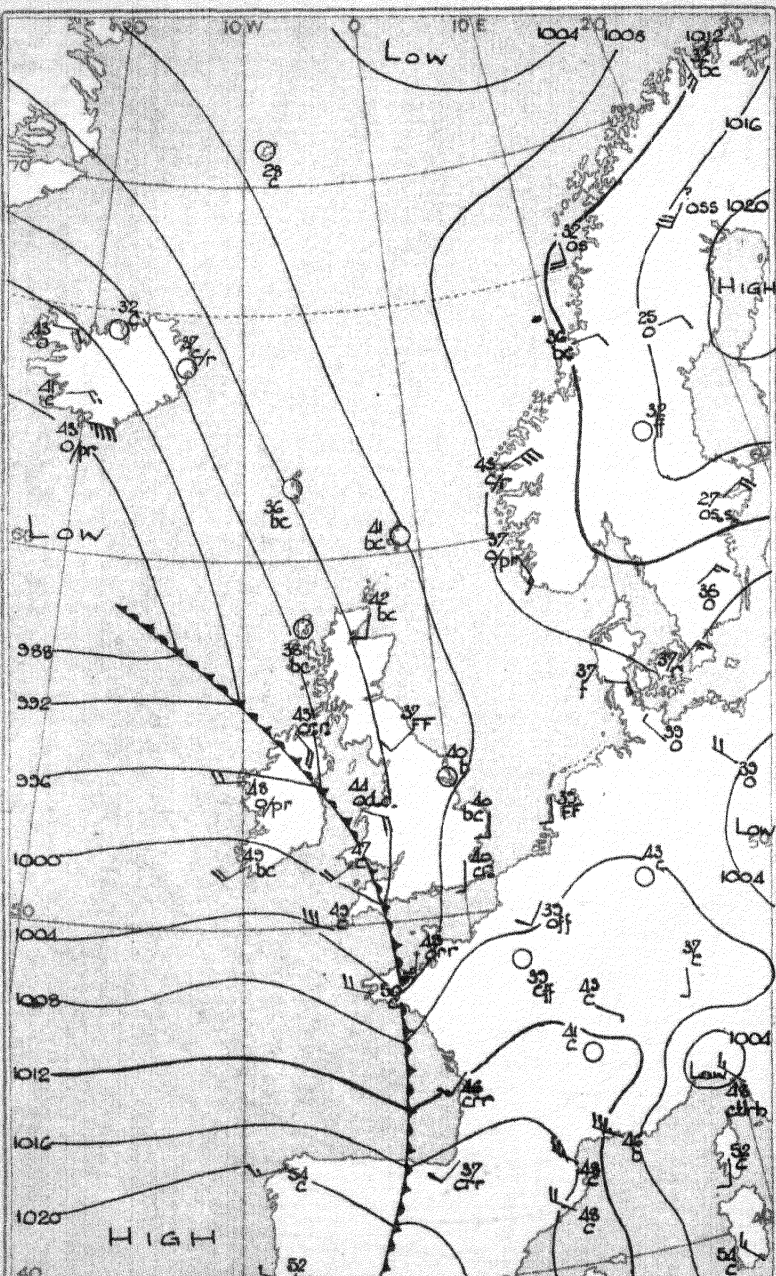
Troughs of Low Pressure (formerly V-shaped Depressions)

Where a well-marked surface of discontinuity cuts the earth's surface the isobars are sharply refracted. The only possible surfaces of discontinuity in nature have the colder air below them, since cold air over warm would be unstable, and it can be shown that the line of discontinuity on the ground has the nature of a trough of low pressure. In the case of a typical moving front the isobars assume the form of a V, often with a sharp point (see Fig. 22). This was the origin of the old term, V-shaped depression, which has now fallen into disuse, owing to the introduction of " frontal " terminology into technical meteorology. The troughs may be either warm fronts, cold fronts or occlusions, and the weather sequence differs accordingly, but in all cases there is a veer of wind as the trough passes. If the trough is of warm-front type, there is persistent rain before it passes, and mild, usually cloudy, weather afterwards. If it is of cold-front type, the rain commences only a short time before the front arrives, and there is heavy rain at the trough, followed by clearing weather. If the front is only moving slowly, as in an elongated V, the improvement is correspondingly slow, and the forecaster has to be on his guard against a new depression forming on the front, which may give a prolonged period of rain. If the trough is an occlusion, the rain commences further ahead of the trough, but otherwise the sequence is similar to that of a cold front. The V-shaped depressions of the older text books had a justifiable reputation as rain-producers. This is because an acute-angled V implies a sharp front and relatively slow motion.

Though a well-marked front is always accompanied by a trough of low pressure, the converse is not true, since there may be a rounded trough without



MARCH 8, 1922, 7h.



MARCH 29, 1927, 7h.

a front, due to a vortex type of air motion. The word " trough " is sometimes used to denote a line drawn through the centre of a depression at right angles to its direction of motion (see Fig. 10). Nowadays the term is generally only applied to the right-hand side of the track. If there are no fronts there (i.e. if the depression is well occluded) there is a typical rounded trough (see Fig. 21). If, however, there is a warm sector, the shape is as in Fig. 15. A cold front or occlusion rarely forms a straight line at right angles to the track of the depression.

Wedges

A wedge is a region of high pressure in which the isobars take the form of an inverted V, but in this case they do not run to a point but are more rounded than in the trough of low pressure. Pressure is also high within the V and not low. A wedge generally projects northward from a high-pressure area and has depressions to the east and the west of it. An example is illustrated in Fig. 23. The wedge moves eastward at a fairly rapid rate between the depressions and sometimes diminishes in intensity as it moves, being worn away, as it were, on the back side by the overtaking depression. Wedges are nearly always regions of fine weather. Probably the weather associated with them is more consistently good than with any other pressure system. They have the good features of an anticyclone without the persistent cloud sheets which so frequently accompany the latter in winter. The good weather is, however, shortlived. The sequence of events is as follows. The depression in front of the wedge passes over a place and the north-westerly wind in its rear brings showery weather with clear skies between the showers. As the wedge advances the showers die away but the bright weather characteristic of north-westerly winds remains. A little high cloud of the cirrus type is frequently to be seen, and it is a feature of these systems that the cirrus is always found to be moving very rapidly from the north-west or north in front of the wedge. As the region of highest pressure approaches the wind drops light and a sheet of high cloud begins to spread over from the westward. This is the precursor of the new depression advancing behind the wedge. The wind springs up from a southerly point, the clouds become thicker and the sequence of weather rapidly becomes typical of the front side of a depression.

Cols

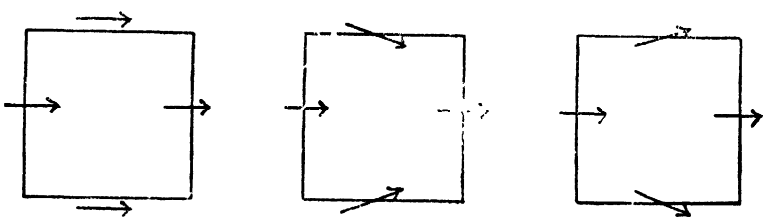
Lastly, we come to the rather complicated pressure system shown in Fig. 24 which is known as a " col ". This is the central region between two highs and two lows. If we imagine the map to be marked like the face of a clock and low pressure systems to be centred on points III and IX with high-pressure systems on VI and XII, there will, at the centre of the face, be a region where the conditions are neither cyclonic nor anticyclonic and where there is no definite wind circulation. This region is a col. It lies over the North Sea in Fig. 24. It is not necessary that the highs and lows should occupy the particular positions named. It may equally well happen that the anticyclones are to the east and west and the depressions to the north and south. This being so it is easy to see that the air within the central region of the col may have come from almost any direction or the col may be the meeting place of different air currents. The weather will be conditioned largely by the past history of the air and will not be the same if this is of polar origin as if it is tropical. It is thus difficult to lay down rules for the weather associated with cols. The absence of any pressure gradient in the central region leads to calms or light airs and these in winter are favourable for the development of fog. In the summer if the sky is clear the intense solar heating associated with the light winds may lead to a development of thunderstorms, provided there is sufficient moisture present in the air to give the necessary condensation.

Cols seldom remain long upon a weather map. The anticyclones on either side may persist, but the region of relatively low pressure between them forms a path along which depressions are apt to travel so that the place of the col on one map will be taken by a depression on the next.

Isallobaric Systems

In the preceding and the present chapters we have thus far dealt with the weather associated with different pressure systems. Before concluding this chapter it will be useful to refer to some recent work which has drawn attention to the importance of isallobaric systems also in connexion with weather. The reader may be reminded that isallobars are lines drawn through places at which the barometer has risen or fallen by the same amount during the preceding three hours. Large positive isallobars show a region of rapidly rising barometer and negative isallobars of falling barometer. It will be convenient to refer to the region where the isallobars have the largest positive values as an " isallobaric high ", in the same way that regions where isobars have their highest value are termed isobaric highs. Similarly a region where the barometer is falling most rapidly will be termed an " isallobaric low ".

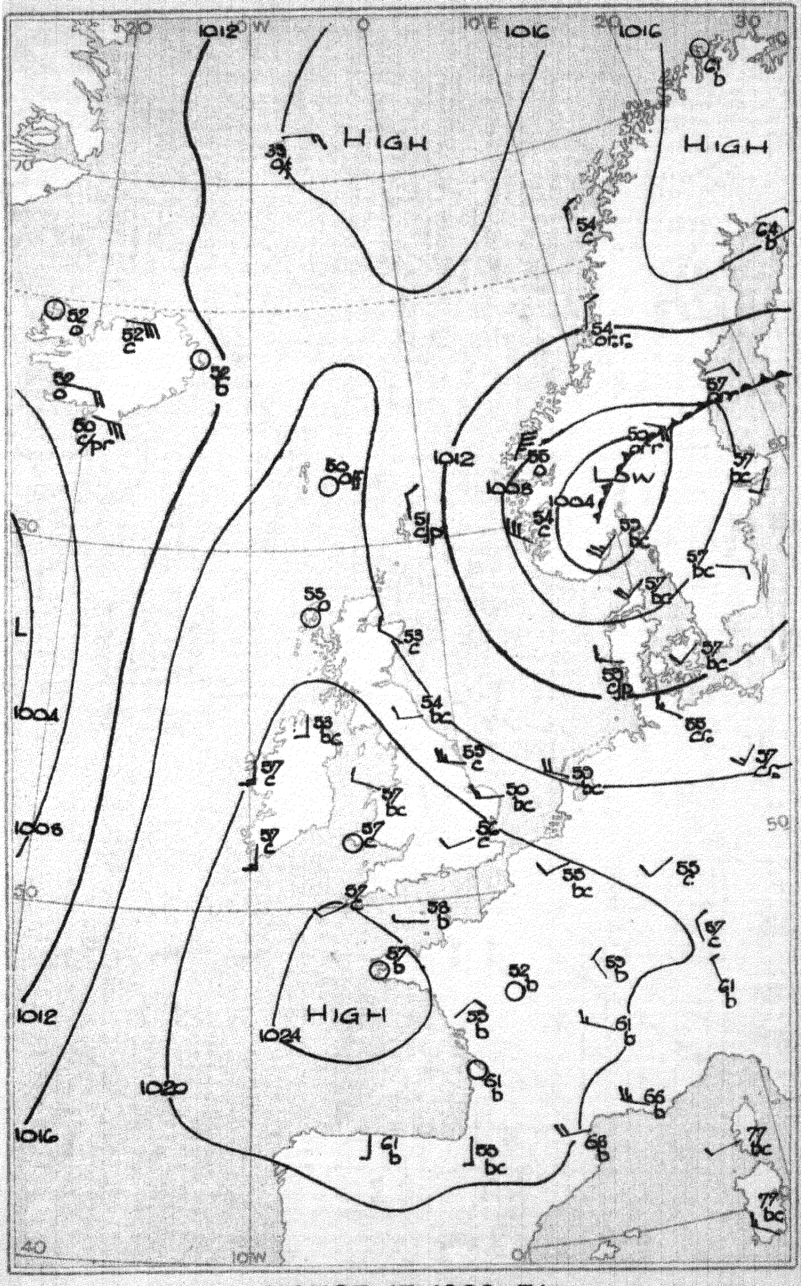
Messrs. Brunt and Douglas, two members of the staff of the Meteorological Office, in a recently published paper have shown that on theoretical grounds an " isallobaric low " must be a region of convergence and an " isallobaric high " one of divergence. It is necessary to explain the meaning of these terms convergence and divergence which are of fundamental importance in meteorology. Convergence indicates a coming together of the air streams over a given region. Imagine a square on the earth's surface the sides of which face north, south, east and west and are each 10 miles in length. If a uniform westerly wind blows over the whole region, the amount of air which leaves the square on the eastern side in any given time is exactly equal to that which enters it on the western side, while none will leave or enter on the north or south. The incoming air will therefore just balance the outgoing. Now suppose that the air is not truly W. over the whole of the square, but blows a little in from the N. along the northern side and a little in from the S. along the southern as in the central figure in the sketch.



No convergence or divergence　　Convergence　　Divergence

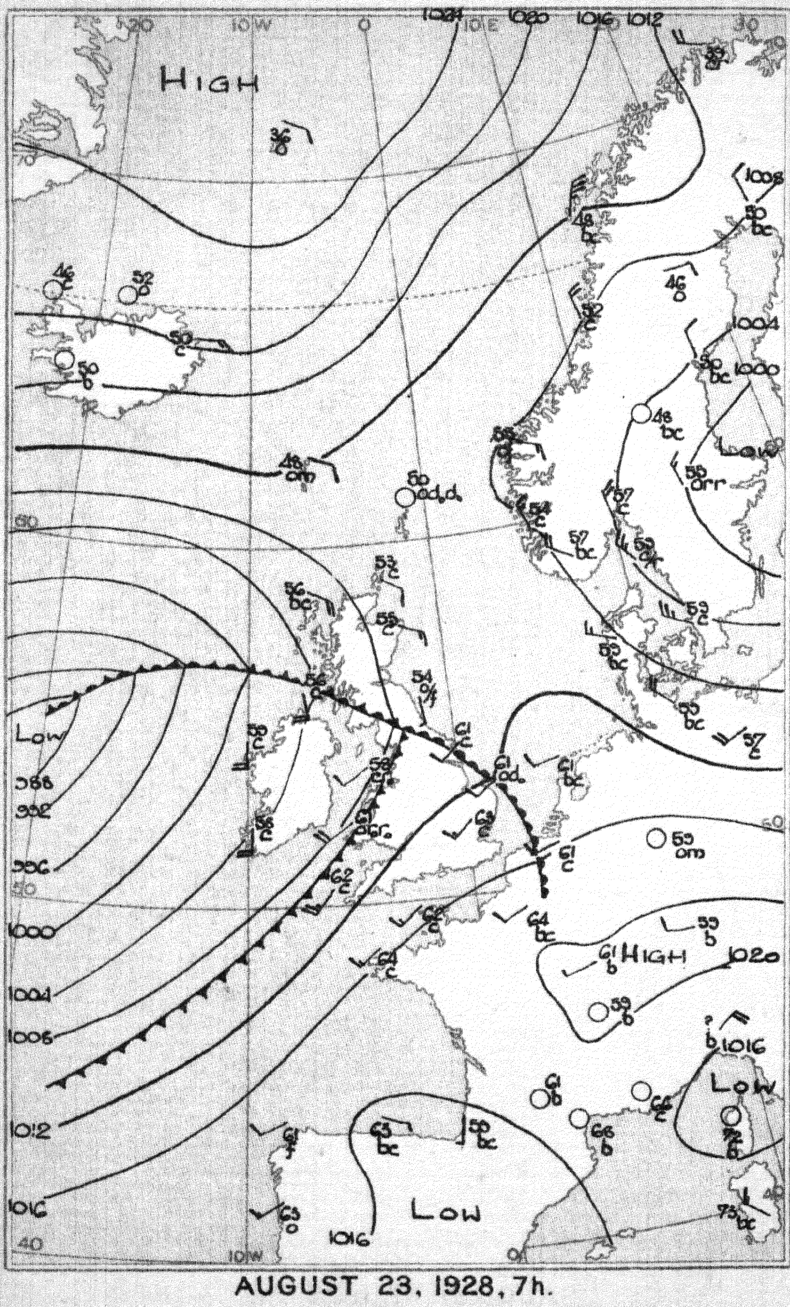
This coming together of the winds is termed convergence and means that more air is entering the square than is leaving it. It is as though a farmer were driving sheep into a field and the sheep were escaping at the same time through a hole in the hedge on the opposite side of the field. If the number that escape in say one minute is equal to the number that are driven in, the number of sheep in the field will not change, but if the sheep are driven in faster than they can escape the number in the field will increase, and if the process is continued long enough the field will become full of sheep. The area 10 miles square which we have been considering is like the field and the air takes the

Fig. 23. To face page 44.



AUGUST 17, 1928, 7 h.

WEDGE



AUGUST 23, 1928, 7h.
Col

place of the sheep. The square is already full of air at the start, and if more comes in than goes out the excess will have to be disposed of by air escaping at the top. This will lead to a rising current. The rising air will be cooled in the manner which has previously been explained and will after a time condense its moisture and, if the process is continued long enough, give rain. Continued convergence of moist air is therefore inevitably associated with cloud and rain. Hence its importance.

Divergence is a blowing apart of the winds and is the opposite of convergence. It is as though the number of sheep escaping through the gap in the hedge were greater than the number driven in, and in the case of the atmosphere the deficiency can only be made good by air descending from above. Descending air is warmed in the same way that ascending air is cooled. The warmth evaporates any cloud particles which may exist and a clear sky is the result. Continued divergence is associated with clear skies.

These facts regarding divergence and convergence have long been known. The important contribution of Brunt and Douglas to our knowledge is their demonstration of the association of convergence with isallobaric lows and divergence with highs. This means that cloudy and rainy weather will be associated with the former, clear skies with the latter. Everyone knows that a rising barometer is an indication of good weather and a falling barometer of bad weather. It has always in the past been considered that this was due to the rising barometer being associated with a retreating depression and the falling barometer with an approaching one. This remains true but we now know that there is an even more direct association between barometric changes and weather than had previously been supposed.

CHAPTER VII

Forecasting from Weather Maps

It would not be possible to give a full account of the methods employed in forecasting from weather maps within the limits of a single chapter, and the task will not be attempted. The aim here is rather to indicate to the reader the lines on which forecasters work so that he may have some understanding of the general principles employed and the difficulties which attend the work.

The making of a forecast comprises three separate problems. First it is necessary for the forecaster to decide in which direction the pressure systems shown on the map will move. Secondly, how their structure will change during the period of the forecast, as it is seldom that systems move without development, and thirdly the effect of topography on weather has to be allowed for. The weather which will be associated with a given pressure system in low-lying country like the eastern counties of England may differ materially from that in more mountainous parts, and the forecaster has to take account of this. It may be well to point out that the atmosphere is obedient to physical laws, so that although weather changes often seem to be haphazard there is really no chance about them. The changes which take place during a given day are absolutely dependent upon the conditions at the beginning of the day, controlled, however, by any external influences which may act upon the earth of which the only one of importance is the heat received from the sun.

If, therefore, the surface conditions and those throughout the atmosphere over the whole globe at a given moment were accurately known and meteorologists had a complete understanding of the physical processes involved, it would theoretically be possible to deduce by a strict mathematical process the weather for succeeding days and weeks. It is probable that a knowledge of the fluctuations in the heat received from the sun during the period would

also be necessary, although it is not fully established that these are of sufficient magnitude to affect the weather from day to day. Further, the temperature of the sea in all oceans would need to be known as this has a considerable effect on the weather. Several separate causes render the method entirely impracticable. In the first place the conditions existing at any moment are not known with anything like sufficient accuracy. A tolerably complete picture of the surface conditions at the standard hours of observation can be obtained from most of the civilized countries of the globe, but there are large parts of the world, particularly over the oceans, where no regular observations are taken. Again, reports of surface conditions are inadequate without data from the upper atmosphere, and such data are still almost completely lacking in many regions. Thus the existing conditions on which the computation would have to be based are to a large extent unknown. Secondly, the atmosphere is so vast and the conditions in it are so complex that the problem presented for solution is quite beyond the powers of mathematicians at present and is likely to remain so in the future.

Notwithstanding these difficulties a courageous attempt was made by L. F. Richardson some years ago to deduce the coming weather by mathematical calculation, an account of the work being given by him in a book entitled "Weather Prediction by Numerical Process". He found it essential to limit the area dealt with to a portion of Europe, and chose for his computations a day, May 20, 1910, when unusually complete upper air observations were available for this area. The attempt was not successful, the changes deduced being markedly different from those which actually occurred but the labour was not wasted as many valuable pieces of information were obtained in the course of the inquiry. It became quite clear to Richardson as the result of working out this definite example that even if successful results had been obtained the method could not at present be regarded as a practicable one for preparing day-to day forecasts. He estimated that it would require an army of 64,000 computers to keep abreast of the weather changes over the globe, that is to compute the coming weather by the time it had arrived.

Although human computation is thus ruled out as impracticable, it is possible to let the weather solve its own equations to a limited extent, and this method is actually employed by forecasters. If two occasions could be found on which the weather over the whole globe was identical and if the heat received from the sun on the two occasions was also the same and likewise the temperature of the oceans, the weather which followed in one case must be an absolute repetition of that which followed in the other, and a forecast for the second occasion could be prepared by noting the weather which had followed on the first. The weather would, in fact, have worked out its own equations. It is inconceivable that over the whole globe the weather can ever actually repeat itself, but it does happen that over a limited area the pressure distribution sometimes approximately resembles that which has occurred on a previous occasion. In order that the forecaster may be able to trace such repetitions the weather maps in the Meteorological Office have been classified for many years in accordance with the pressure systems prevailing in the neighbourhood of the British Isles, and an index of the dates on which the different types of pressure distribution have occurred is kept for reference. The forecaster who wishes to find previous cases similar to that with which he is dealing has only to note which type of conditions are shown on his map and turn up the index in order to find dates when similar conditions have occurred in the past. He will not find any case which exactly resembles the present one, and it will be necessary for him to decide which, if any, of the maps indexed bear a sufficiently close resemblance to it in essential particulars to be of use for his purpose. Having found such a case he studies the sequence

of weather which followed it and is guided by this in preparing his forecast. This method is not in practice much used for short-period forecasts of less than 24 hours, but when it is desired to give an indication of the changes which will occur over a longer period amounting perhaps to two or three days, good results may often be obtained by employing it.

A method of determining the probable motion of pressure systems which is sometimes used is to assume that their motion in the future will be a direct continuation of that in the recent past, that they will continue to move in the same direction and at the same speed. The rule is one which must be applied with great caution, particularly in the neighbourhood of coast lines. Thus a depression which has been moving steadily over the Atlantic may, when it approaches the coast of Europe and begins to draw in dry air from a land source instead of moist air from the ocean, immediately change its line of progression. Mountain ranges also affect the travel of depressions. This is a matter of great importance in countries like Norway where a long line of mountains fronts the sea. In the British Isles where the mountains are confined to a few isolated regions, Wales, the Lake District and the Highlands of Scotland, the matter is one of less importance. It is, however, chiefly over the oceans that the rule may be applied, and it is in such a region where reports are often too few in number to provide a detailed knowledge of the conditions that the rule is of most use.

The most important aid which the forecaster has in determining both the direction of movement of pressure systems and the changes which are taking place in them, is found in the reports of barometric tendency which he receives from all observing stations. There is no part of the message which would be more missed than this. The tendency shows what change of pressure has occurred in the past three hours, and the " characteristic " whether the change has proceeded uniformly throughout the period or has been broken, as, for example, by an initial fall of pressure being turned later into a rise. Thus the forecaster knows what changes are actually taking place at the moment and can tell in which way the pressure systems are moving ; he can also form a fairly accurate idea of the way in which they are likely to move in the period covered by his forecast. The method of using tendencies will be made plain if we again refer to Fig. 10 on p. 31, which shows Abercromby's picture of a depression. It will be clear that as the depression moves in the direction of the arrow, the barometer will be falling most rapidly at places directly in front of the centre along the path, and will be falling also, though less rapidly, at all places on either side of this line which are within the influence of the depression. At places on the trough line the barometer will have ceased to fall and will be on the point of rising, while behind the trough line there will be a region of rising pressure, the rise being most marked at places directly behind the centre on the path of the depression. Thus we obtain the rule that a symmetrical depression moves towards the region where pressure is falling most rapidly and away from the region where it is rising most rapidly. It sometimes happens that the most rapid fall of pressure on the map is not just in front of the centre of the depression but at some distance away. It will be clear that if a fall of this kind continues in a certain spot it may lead to the pressure falling lower at that spot than it is in the centre of the depression. This will lead to the formation of a " secondary ". The forecaster then is watchful for any abnormal fall at some distance from the centre, and regards such as an indication of the formation of a secondary rather than as indicating the direction in which the main centre is moving.

We have seen that if Abercromby's symmetrical depression moves uniformly pressure will fall in front and rise behind, and in general the rate of fall and rate of rise will not be widely dissimilar. It is sometimes found

that the fall of pressure in front is much less rapid than the rise behind or it may even be that the barometer is steady in front and rising rapidly behind. This will indicate that the depression is filling up as it travels, that is, that pressure at its centre is rising. Conversely if the fall of pressure in front is large but there is little rise behind, this shows that the depression is growing deeper. Barometric tendencies thus provide invaluable indications of the changes which are taking place in pressure systems as well as regarding their direction of movement.

It has been explained in an earlier chapter (p. 26) that isallobars are sometimes drawn through places having equal barometric tendencies and that these isallobars show in a clear manner the regions where the barometer is rising and those where it is falling. Isallobars were first used by a Swedish meteorologist, Nils Ekholm, who claimed that isallobaric systems moved with more regularity than ordinary pressure systems so that when the movement of an isallobaric high or low could be traced on past weather maps, its future progress might be determined by assuming that it would continue to move in the same direction and at the same rate in the future, as in the past. This being so, it would be possible to predict the regions where pressure would be rising and falling in the future and to decide upon the rate of the rise or fall. With these conditions known it would clearly also be possible to calculate the height of the barometer in the different regions 6 or 12 hours in advance and to plot a pressure map for this epoch. The forecaster would therefore be able to solve two of his three problems and to decide in which direction the pressure systems were going to move and what changes were going to take place in them. A good deal of use is made of this method in some meteorological services, but as has been already stated the British practice is rather to enter the individual barometric tendencies on the map and learn from the readings themselves than to make any great use of systems of isallobars.

The methods just described for determining the movement and changes of pressure systems have been based on a direct interpretation of the readings shown upon the map, and while experience is necessary for their proper use the reasons behind the rules are fairly clear, even to those not versed in meteorology.

We will now turn to the work of Bjerknes. The chief value of this lies in the insight which it gives into the mechanism of a depression. The formulation of rules to guide the forecaster must be regarded in this case as of secondary importance. A forecaster will clearly be in a much better position to anticipate coming changes of weather if he knows the reason for the weather which exists at the time than if he is in ignorance of this. Thus if, for instance, rain is seen to be falling over a certain area which can be associated with a warm or cold front of Bjerknes, the forecaster can issue a forecast as to its movement and probable development with much more confidence than if he merely sees an area of rain on his map without being able to assign any reason for its existence. The contribution of Bjerknes towards an understanding of the mechanism of depressions has already been great and will be greater as the passage of time affords further opportunity for exploring the application of his theories. As regards the rules which he puts forward these are few in number and simple in application. The first rule (1) is that a depression will move parallel to the isobars in its warm sector. If Fig. 15 on p. 37 is examined it will be seen that the isobars in the warm sector, that is the region between the cold front and the warm front, are drawn as straight lines and these lines indicate the direction in which the depression will travel. The chief applicability of this rule is in the case of depressions over the Atlantic which have a well developed warm sector, though unfortunately the observations received from ships are

not always sufficiently numerous for the isobars in the warm sector to be drawn with full confidence. Depressions which reach the British Isles are as a rule occluded, that is the warm sector is no longer present on the earth's surface and the rule, therefore, ceases to be applicable. A second rule (2) is that a depression with a well-marked warm sector will increase in intensity and a third rule (3) that when a depression becomes "occluded" it will shortly commence to fill up. Rules (2) and (3) are of value in forecasting even though, as is common in meteorology, exceptions occur not infrequently. For example, there appear to be cases where a depression goes on growing deeper for some time after the stage of occlusion has been reached, in defiance of rule (3).

A feature of the weather which forecasters cannot afford to neglect, although its explanation is not at present clear, is the tendency to persistence of type. This is particularly noticeable when a long spell of dry weather has occurred. It seems in such a case as though a great deal more were required to break up the weather than might be expected. After such a spell a depression may encroach on the British Isles, which would normally give rain in the region which has suffered from drought, but the disturbance will pass away either without breaking the spell or after giving at the most but a sprinkling of rain. In another case when the weather has been persistently unsettled the very smallest secondary, which is shown by a barely noticeable deflection of the isobars, seems to give rain. Surface observations give no clue to the cause of this persistence. It is probable that the cause will be found when readings taken in the upper air afford meteorologists as good a knowledge of the conditions in the higher layers of the atmosphere as they have of the surface conditions. The work of Bjerknes has directed particular attention to the importance of these higher layers, and by a fortunate coincidence the use of aeroplanes for meteorological observation developed during the war has provided an effective means of studying the conditions. There has been a notable advance during the past few years in our understanding of the processes at work in the upper atmosphere, and further progress in forecasting must be intimately associated with a continuance of the advance in the future.

It will be of interest before leaving the movement and development of pressure systems to mention a few situations of peculiar difficulty with which the forecaster from time to time finds himself confronted. This may help to give the reader an insight into the reason for the complete failure of some forecast such as has unfortunately to be chronicled from time to time. The most difficult case with which a forecaster has to deal is when the observations from the west coast of Ireland give a slight, though perfectly clear, indication of a depression or a secondary moving in from the Atlantic. It may have been evident from ships' observations that no important disturbance previously existed over the ocean in the vicinity of the Irish coast, and the forecaster has to decide whether the disturbance which is shown will pass harmlessly up the western seaboard as a very slight secondary with a few clouds and perhaps a sprinkling of rain, or whether it will develop into a major disturbance spreading its effect over the whole country in the form of strong winds and heavy rain. Even the most experienced forecaster may go astray in these circumstances. Another difficult situation which sometimes arises is when, after a long spell of fine anticyclonic weather, the barometer commences a steady fall over the whole region occupied by the anticyclone. No definite depression may develop and the fall of pressure may continue for perhaps several days without any deterioration of the weather, but the forecaster knows that a break must come ultimately and if he makes a mistake in timing its arrival a bad forecast will result. In this type of case upper air observations are of material assistance.

One further example of a difficult situation will suffice. In thoroughly unsettled conditions with constant and rapid changes taking place, a map sometimes presents itself which contains no definite indication of what the next change will be. Barometric tendencies may all be small and the pressure systems for the time be stationary. The forecaster knows that conditions are thoroughly unstable and that important developments in the period for which he has to forecast are certain. He sees little to guide him in deciding what these developments will be.

It was stated at the beginning of this chapter that the problem before the forecaster was a threefold one. He has to decide in the first place on the movement of the pressure systems, secondly upon their probable development, and thirdly he has to consider the weather which they will give in different parts of the country, the topography of which differs widely. It is not possible to enter fully here into this matter of the effect of topography on weather. It forms an important branch of forecasting to which one or two chapters might easily be devoted. Some further reference will be made to it in discussing the choice of forecast districts in the next chapter. That marked differences of weather occur in different localities is known to all. Thus those who go to the mountainous parts of the country for their holidays are, or should be, more prepared for rain than those who remain in the flatter eastern counties. Agriculturists who wish to escape ground frost in the spring and autumn know that they should avoid the bottom of a valley and seek rather the top or sides of a hill. It is common knowledge that river valleys are peculiarly liable to fog. In each of these cases and in many others the weather depends upon the locality, and of all these points the forecaster must take account. Clearly he cannot, when making forecasts for whole districts, distinguish between the tops of the hills and the bottoms of the valleys, but he can and must take account of the different characteristics of mountainous and flat districts and bear these in mind in drawing up his forecasts, and there are other matters of a like nature of which he must not be unmindful.

It is in supplying detailed forecasts for a particular locality that a forecaster with local knowledge stands at an advantage. Branch offices at which local forecasts are prepared are maintained by the Meteorological Office in different parts of the country, principally at airfields. Weather maps are drawn regularly at these centres from the reports received by wireless, and detailed forecasts for the locality are prepared from the maps. The forecasts issued from the Meteorological Office by wireless are also picked up in order that the meteorologist may be informed of the view of the situation taken at Headquarters. The keeping of local weather records forms an important part of the work of such a centre. At the commencement of the work the advantage which the local forecaster has over his confrère at Headquarters is slight as he lacks that local weather knowledge which will later prove so valuable. The records taken at the station and the experience gained will after a time supply this local knowledge, and the forecaster will then be able to make allowance for any peculiarities of the climate which the district may possess. Thus when the forecaster at Headquarters indicates fog locally, meaning that fog will occur in some places but not in others, the district forecaster may either from his knowledge omit any reference to fog knowing that it is unlikely to develop in his locality under the conditions prevailing, or on the other hand he may feel justified in giving a definite forecast of fog omitting any qualifying adverb. Similar cases will occur with other elements of the weather where the local forecaster can by modifying the forecast received from Headquarters increase its usefulness to those in his immediate locality.

CHAPTER VIII

British Forecast Districts and some Forecasts

In this chapter some forecasts which have been issued by the Meteorological Office will be examined and the reasons which actuated the forecaster explained.

Before doing this it will be well to say a few words explanatory of the forecasts supplied to the newspaper press. The principal forecasts are those issued on the 6h. weather map which are ready for the evening newspapers by not later than 10h. 30m. and those on the 18h. map which are prepared for the newspapers published the following morning. The morning forecasts cover the 24-hour period from noon to noon. The evening forecasts which appear in the papers the following morning refer to the period from 6h. in the morning until the following midnight.

It will be seen that an interval of some hours elapses between the time to which the map refers and the time when the forecast comes into operation. It is necessary to bear this in mind when examining forecasts or it may appear curious that in some cases the forecast for the initial part of the period should differ widely from the weather which is shown to exist at the time on the map.

The weather over the British Isles often shows such variety that it is difficult to word one comprehensive forecast for the whole country, and for the forecasts the area is divided into 20 districts as shown on the map in Fig. 25 and in the table on p. 53. As district 13 in the west of Scotland is sub-divided into 13A and 13B, in effect there are 21 forecast districts for the British Isles. If the land were flat without mountain ranges or high hills the variety of weather in different districts would be due almost entirely to the effect of the pressure systems. The country could then for forecast purposes be divided into a set of districts of approximately equal area, and the choice of the boundary lines would not be difficult. Actually in a country like the British Isles the mountains have such a considerable effect upon the weather that, in choosing the forecast districts, it is necessary to pay more attention to the orographic features than to the paths of pressure systems. The effect of a range of mountains is to produce a heavy rainfall in the immediate vicinity and a relative absence of rainfall on the lee side. This absence of rain will be felt on the east side on occasions when the normal westerly wind prevails but on the west of the range should an easterly wind be blowing. It is therefore necessary, so far as possible, to assign different forecast districts to a mountainous region and to the country to the east and west of it.

When the forecaster has decided upon the districts which would be most suitable, a practical difficulty arises in defining them so that the user may know in which district he is situated. The only practical method of separation is by counties. County boundaries were not chosen with any regard to meteorological conditions, and they are not in all cases suitable for the purpose, but it has been found possible to adhere to these boundaries in England, Ireland and Wales. In the north of Scotland an exception had to be made, and the division between districts 13B and 15 cuts across certain counties.

A few words on some of the districts may be useful. It will be seen that district 2 is one of the largest and covers all the flat ground of Lincolnshire

and the eastern counties. The weather is as a rule fairly uniform over this area, there being no mountains and few hills to cause local variations. District 1 contains the North and South Downs of Kent, Surrey and Sussex, and further west the Wiltshire Downs. These hills rise to some 800 ft.; they

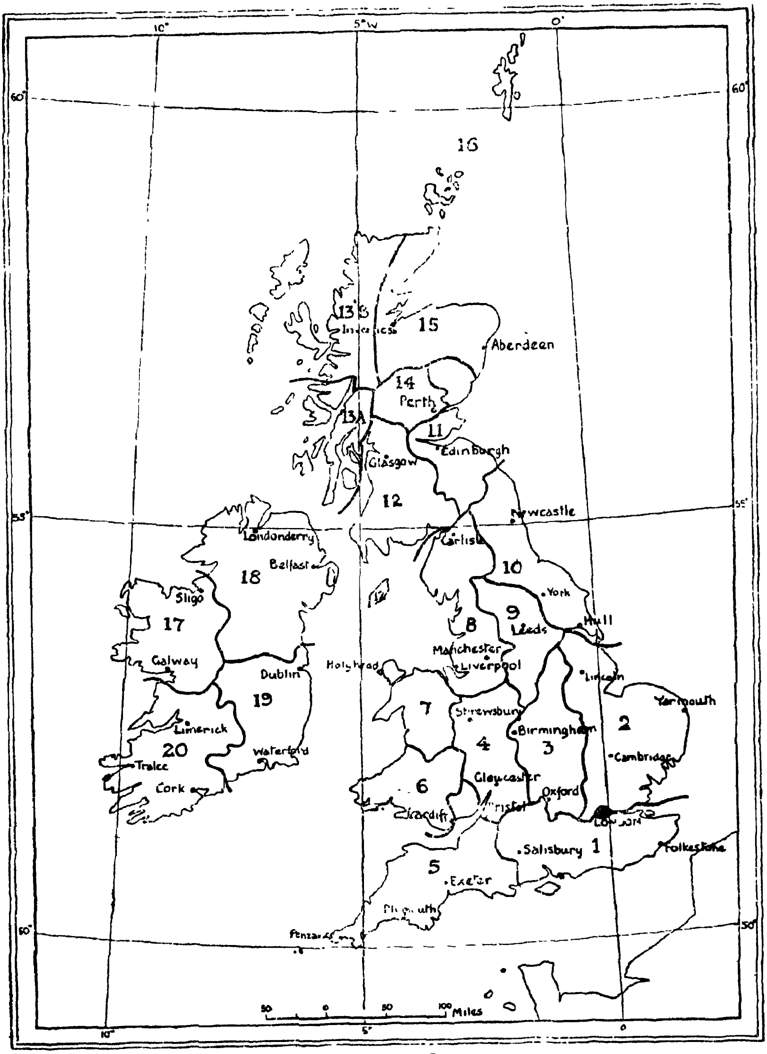


FIG. 25.—FORECAST DISTRICTS

are high enough to influence the weather, though not to the same marked degree as the high ground of Exmoor and Dartmoor which occupies a considerable part of district 5, south-west England. It will be found in Meteorological Office forecasts that districts 1 and 2 are frequently grouped together and given the same forecast but that it is less common to include district 5 within the same bracket. This is to a considerable extent due to the different orographic features of the two regions.

FORECAST DISTRICTS

1. *England, S.E.*
   Kent.
   Sussex.
   Surrey.
   Hampshire
   Berkshire.
   Wiltshire.

2. *England, E.*
   Essex.
   Middlesex.
   Hertford.
   Bedford
   Huntingdon.
   Cambridge
   Suffolk.
   Norfolk.
   Lincoln.

3. *Midlands, E.*
   Buckingham.
   Oxford.
   Northampton
   Warwick.
   Leicester.
   Rutland
   Nottingham.

4. *Midlands, W.*
   Gloucester.
   Hereford.
   Worcester.
   Shropshire.
   Stafford.

5. *England, S.W.*
   Dorset.
   Somerset.
   Monmouth.
   Devon.
   Cornwall.

6. *Wales, S.*
   Glamorgan.
   Brecknock.
   Carmarthen.
   Pembroke.
   Cardigan.
   Radnor.

7. *Wales, N.*
   Montgomery.
   Merioneth.
   Flint.
   Denbigh.
   Carnarvon.
   Anglesey.

8. *England, N.W.*
   Cheshire.
   Lancashire.
   Westmorland.
   Cumberland.

9. *Midlands, N.*
   Derby.
   Yorkshire, W

10. *England, N.E*
   Yorkshire, N & E.
   Durham.
   Northumberland.

11. *Scotland, S.E.*
   Roxburgh.
   Selkirk.
   Peebles.
   Berwick.
   Haddington.
   Edinburgh.
   Linlithgow.
   Clackmannan
   Kinross.
   Fife.
   Forfar.

12 *Scotland, S.W., and Isle of Man.*
   Isle of Man.
   Dumfries.
   Kirkcudbright.
   Wigtown.
   Ayr.
   Lanark.
   Renfrew.
   Dumbarton.
   Stirling.

13A. *Scotland, W.*
   Argyll.
   Bute.

13B. *Scotland, N.W.*
   Hebrides.
   Western parts of Inverness, Ross and Cromarty, Sutherland. (Boundary line runs from Rannoch Station through Fort Augustus, Beauly and Lairg to Melvich).

14. *Mid. Scotland.*
   Perth.

15. *Scotland, N E.*
   Kincardine.
   Aberdeen.
   Banff.
   Elgin.
   Nairn.
   Caithness.
   Eastern parts of Inverness, Ross and Cromarty, Sutherland.

16. *Orkneys and Shetlands*

17. *Ireland, N.W.*
   Galway.
   Roscommon
   Mayo.
   Sligo.
   Leitrim.

18. *Ireland, N.E.*
   Meath.
   West Meath.
   Longford.
   Cavan.
   Fermanagh.
   Monaghan
   Louth.
   Armagh.
   Down.
   Antrim.
   Londonderry.
   Tyrone.
   Donegal.

19 *Ireland, S.E.*
   Waterford.
   Wexford
   Kilkenny.
   Carlow.
   Wicklow.
   Offaly.
   Leix.
   Kildare.
   Dublin.

20. *Ireland, S.W*
   Cork.
   Kerry.
   Limerick.
   Tipperary.
   Clare.

Further north the mountainous country of Wales is divided centrally into two parts, North Wales and South Wales, the lower land of the Upper Severn basin to the east forming a further district, the western Midlands. In the north of England, the Pennine Chain deserves a district to itself, but it is necessary to limit the number so that this must be foregone, and the same may be said of the Lake District, which might with considerable advantage be separated from the low ground of Cheshire to the southwards. The most serious difficulty of all is found in Scotland where the mountains reach their

greatest height and where very wide differences of weather often occur within a comparatively short distance. It is almost impossible in a country such as this to choose forecast districts which are suitable for all the differing conditions which may arise. Much thought has been expended on the matter, but the final choice must from the nature of the case be a compromise and therefore not entirely satisfactory.

The information issued to the newspapers comprises not only the district forecasts but also a "general inference" and "a further outlook". The "general inference" consists of a short statement about the pressure systems which are expected to affect the weather in the period covered by the forecasts and the changes in them which are likely to occur, with a few words on the weather conditions anticipated over the country as a whole. To the reader who has no knowledge of meteorology the general inference may appear superfluous. It is hoped that the reader of this book will not so regard it, but will find that the light which it throws on the reasons which have actuated the forecaster in drawing up his forecasts makes its value as great as, or even greater than, that of the individual district forecasts. The "further outlook" consists of a brief indication of the type of weather expected over a period beyond that covered by the detailed forecasts. It does not, as a rule, refer to any specific period of time, but where no statement is made to the contrary may be taken to cover the weather of one or two days after the termination of the short-period forecasts. It is impossible when looking this distance ahead to determine the weather changes with the same detail as for the coming 24 hours, and the wording adopted for a further outlook is therefore necessarily somewhat vague. It may, and often does, take such a form as "unsettled" or "no important change." It may be used as an indication whether wet and disturbed or fair, quiet weather is probable, but it does not as a rule go beyond this.

It will be useful here to refer to one difficulty with which the forecaster is faced which is not evident to the user of the forecasts, and that is the difficulty of having to work on incomplete information. Owing to the rapid changes which occur in the weather it is essential that the forecasts should be placed in the hands of readers as soon after the observations are made as possible, and in addition to this, the newspapers are always anxious, and rightly anxious, to obtain the latest information for their several editions. The forecaster is therefore constantly being pressed to issue forecasts before he has had adequate time to study the latest developments of the situation as shown on the map and even before all the reports from observing stations are received. This pressure he must resist, but he cannot be entirely oblivious of it, and it does occasionally happen that when the work is partly done an additional observation is received from a ship on the Atlantic which very materially modifies the outlook. The hasty readjustment of ideas which is necessary in a case of this kind may lead to the forecasts lacking some of the precision of wording which the forecaster would wish to employ.

We will now pass to a discussion of some individual forecasts. Twelve examples of forecasts issued on the 7h. map for certain days during 1928 have been selected to illustrate different types of weather conditions, and notes have been made on each occasion indicating the reasons which led the forecaster to his decision. Each example occupies one double page. The weather map covers one page, while the general inference, forecasts, further outlook and explanatory remarks are printed on the opposite page. It is impossible on the small maps which are reproduced to give the detail which the forecaster requires in his work; the maps cannot do more than illustrate rather broadly the conditions which existed at the time. Further, one map alone without the preceding charts for at least the past 24 hours would, in any case, be insufficient.

The notes given do not include as a rule any statement concerning the accuracy or otherwise of the forecasts. In most cases the weather developed as anticipated. In one or two instances where there was a partial failure and the cause of such failure raises a point of general interest this has been mentioned.

It will be necessary in explaining certain of the forecasts to refer to the terms used by Bjerknes in his description of a depression. The meaning of these terms has already been given in Chapter V, but a short recapitulation may be permitted in view of their importance in modern forecasting. In the Bjerknes theory a depression is regarded as consisting of two parts, a cold sector and a warm sector, the latter being usually on the southern side of the centre and seldom occupying more than one quarter of the whole. The cold sector contains polar air, the characteristics of which are bright skies with showery weather and low temperature, though this last feature is often not well marked in the surface readings; the warm sector contains tropical air in which the sky is cloudy, and slight rain or drizzle falls at times, the air being mild and humid. The boundary lines between the equatorial and polar air are termed "fronts," that which occupies the right-hand position in the normal depression being the warm front and that on the left-hand the cold front. These fronts are regions of rain and much heavy cloud. At the cold front the cold air is constantly pushing its way under the warm air like a wedge and lifting it from the surface, while at the warm front the warm air tends to rise above the cold air which lies in its path. Thus the warm sector gradually becomes narrower as the warm air is lifted off the ground, and finally the cold front overtakes the warm front, the line where the two coalesce being termed the "line of occlusion".

Above this line the warm air will still be found in the upper regions of the atmosphere, though after a time it will have been lifted some distance from the surface. The cloudy and rainy characteristics of the warm and cold fronts will persist at the line of occlusion. It might be thought that with polar air both in front of and behind the line there would be no temperature contrast, but this is seldom the case, the polar air being usually colder in the rear in summer, but colder ahead of the occlusion near ground level over land in winter. For this reason a line of occlusion may easily be mistaken for a warm front. A distinguishing feature is found in the nature of the weather behind the line. In the case of an occlusion this has the bright but showery features of polar air while in the case of a true warm front the weather is of the cloudy type associated with tropical air. If these points are borne in mind it will help to an understanding of several of the remarks made in the succeeding pages.

SECONDARY DEPRESSION.—7h. Tuesday, January 10, 1928.

Forecasts for the 24 hours commencing 15h. G.M.T. Tuesday, January 10, 1928.

General Inference.

An intense secondary depression off the Hebrides will move rapidly north-eastwards, while the primary off southern Iceland is tending to move a little south-east. Weather will continue stormy and unsettled and gales will be rather severe to-day in most northern districts.

Districts.	
1. S.E. England 2. E. England 3. E. Midlands 4. W. Midlands	Wind SW., veering W., fresh or strong, perhaps touching gale force locally, moderating by to-morrow; occasional rain later to-day, fine to-morrow apart from scattered showers; mild.
5. S.W. England 6. South Wales	Wind SW., veering W., strong to a gale, moderating later; some rain at first, bright periods later, but occasional showers; mild.
7. North Wales 8. N.W. England 9. N. Midlands 10. N.E. England	Wind SW., veering W., gale, moderating by to-morrow to fresh or strong wind; rain at first, bright intervals later, but showers of rain, hail or sleet; perhaps local thunder; rather mild, then somewhat colder.
11. S.E. Scotland 12. S.W. Scotland and Isle of Man. 13 (A) W. Scotland	Wind veering W., gale, moderating later to fresh or strong wind; showers of rain, hail or sleet, with snow on hills; perhaps local thunder; bright intervals moderate or rather low temperature.
13 (B) N.W. Scotland	As 15—16.
14. Mid Scotland	As 11—13A.
15. N.E. Scotland 16. Orkneys and Shetlands	Wind changing to NW., gale, backing W., moderating somewhat; rain, then showers of rain, hail or sleet, with snow on hills; perhaps local thunder; bright intervals; moderate or rather low temperature.
17. N.W. Ireland 18. N.E. Ireland 19. S.E. Ireland 20. S.W. Ireland	Wind W., a gale at first, moderating to strong breeze; showers of rain and hail; perhaps local thunder; bright intervals; moderate temperature.

Further Outlook.

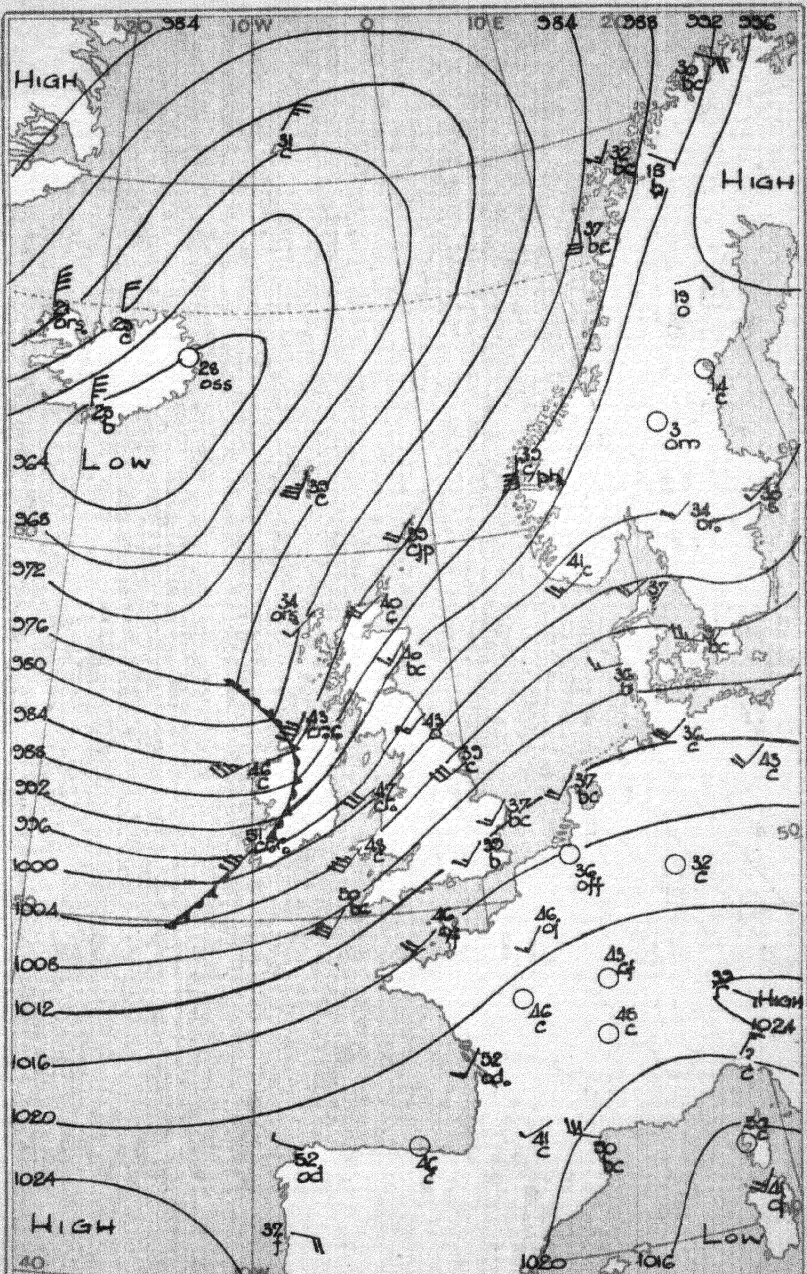
Stormy and unsettled but considerable bright intervals in the south and east of England. Snow showers on high ground in the north.

The principal feature of the map was an intense secondary depression off the Hebrides which the general inference indicates to have been moving rapidly north-eastwards. The secondary was not shown as having closed isobars at the time, though these developed later. The statement indicating a movement to the north-east was based on the general tendency of secondaries to move in a counter-clockwise direction round their primaries, the primary in this case being centred off the south of Iceland. That the rate of movement was rapid was indicated both by the distance travelled since 1 a.m., deduced from the 1 a.m. chart, and by the very large barometric tendencies in front of the secondary on our north-west coasts. The largest of these was at Malin Head in the extreme north of Ireland where the barometer had fallen 13 mb. in the past three hours.

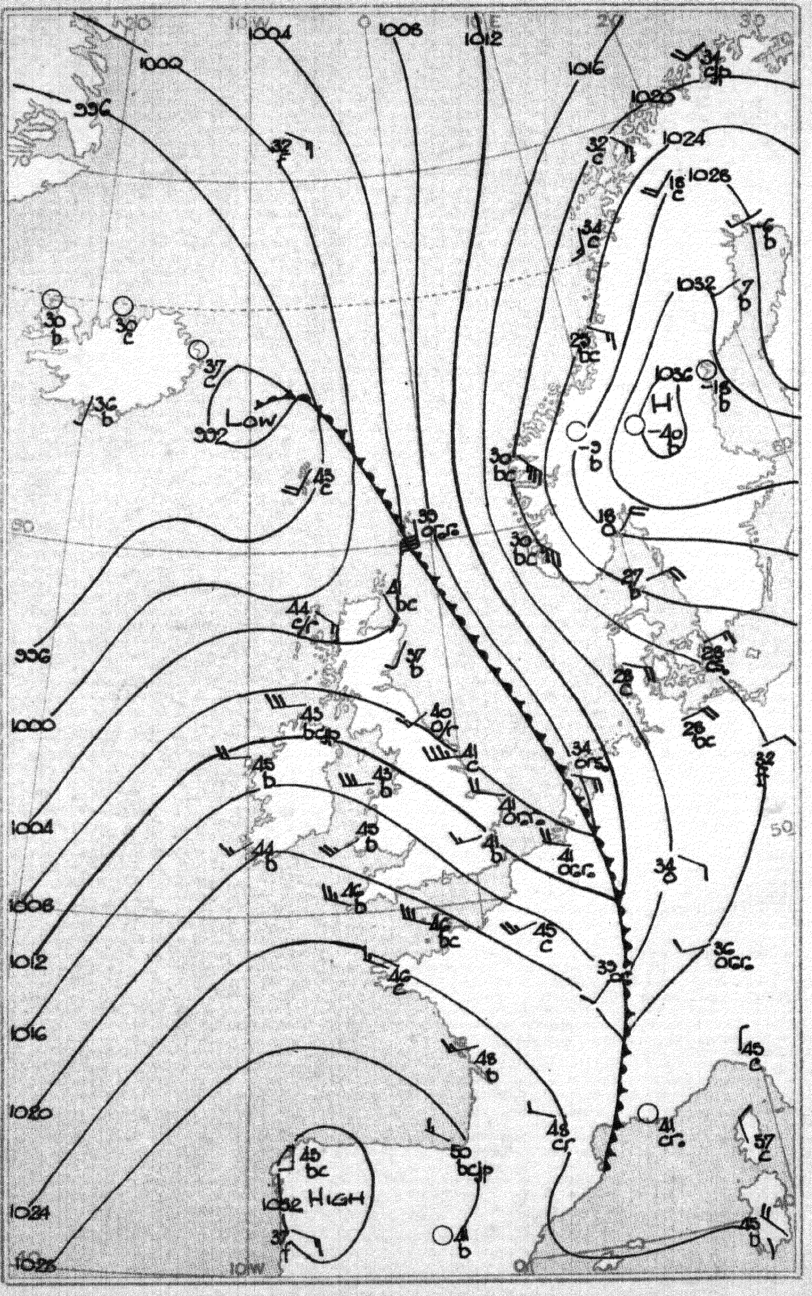
It would be tedious to discuss each of the separate district forecasts in detail, but the main underlying principles will be considered. The wind was expected to veer to the W. as the trough of low pressure running from the main depression through the secondary passed eastwards across the country, while in the extreme north of Scotland a further temporary veer to the NW. was forecast. This was based on the probability that the very rapid fall of pressure in the north of Ireland would lead shortly to the development of a separate centre of low pressure in that region in the manner indicated on page 47, and as this centre travelled north-eastwards the north-westerly winds behind it would be felt in the north of Scotland. The intensity of the disturbance led to a forecast of gales in most districts, but these were expected to moderate after a short time, the effects of a quickly moving secondary of this nature being quickly past.

The forecasts of weather were based on the fact that stale polar air, that is polar air which has lost most of its coldness by prolonged travel over the warm waters of the Atlantic, covered the British Isles, being separated from the more truly polar air which was over the Atlantic at the time by a " line of occlusion " which lay over Ireland.

The presence of genuine polar air over the Atlantic was shown by a report from the liner *Melita* about 500 miles westward of Ireland. It will be remembered that cloud and rain precede the passage of an occlusion followed by bright but showery weather behind. The forecast then took this form but in the north the showers were expected to include some hail or sleet with snow on the hills and perhaps local thunder. This wintry type of shower was based on the coldness of the air which was shown by the *Melita's* report to be travelling in from the Atlantic, it being known further that air of this nature is liable in winter months to lead to thunderstorms.



JANUARY 10, 1928, 7h.



JANUARY 19, 1928, 7h.

WEDGE.—7h. Thursday, January 19, 1928.

Forecasts for the 24 hours commencing 15h. G.M.T. Thursday, January 19, 1928.

General Inference.

A wedge of high pressure crossing the British Isles will give a short fine interval but a deep depression on the Atlantic will soon extend its influence over the British Isles.

Districts.	
1. S.E. England 2. E. England 3. E. Midlands 4. W. Midlands	Wind W., moderate or fresh, backing S. later; fine to-day, some rain to-morrow; rather mild.
5. S.W. England 6. South Wales 7. North Wales 8. N.W. England	Wind backing S., moderating then becoming fresh or strong, perhaps a gale fine to-day, some rain to-morrow; mild.
9. N. Midlands 10. N.E. England 11. S.E. Scotland	As 1—4.
12. S.W. Scotland and Isle of Man 13. (A) W. Scotland 13. (B) N.W. Scotland 14. Mid Scotland 15. N E. Scotland 16. Orkneys and Shetlands	Wind W., moderating temporarily and backing S., strong to a gale later fine at first apart from local showers, heavy rain later; mild.
17. N.W. Ireland 18. N.E. Ireland 19. S.E. Ireland 20. S.W. Ireland	Wind between S. and SW., strong to a gale at times; becoming dull and rainy; mild.

Further Outlook.

Unsettled and rather mild.

The weather over the British Isles was at this time controlled by a wedge of high pressure, the centre line of which extended from the Bay of Biscay northward off the west of Ireland. A deep depression was shown by ships' reports to be situated far out on the Atlantic. The fact that the weather was fine over the whole of England and Ireland, including even the western coast where the effect of the Atlantic depression might have been expected to be felt, coupled with the fact that the barometer was rising over the whole of the British Isles, might have led an inexperienced forecaster to have anticipated that the fine weather would continue at least for 24 hours. The general inference shows that this view was not taken, but that the wedge was expected to cross the British Isles and give but a short interval of fine weather. It was pointed out on p. 43 that a characteristic of a wedge is that the fine weather associated with it is of short duration and soon gives place to the cloud and rain of the depression on its western flank. It was this knowledge which guided the forecaster.

In preparing the detailed forecasts the whole of the east of the country was grouped together from south-east England to south-east Scotland, and in this area a moderate or fresh westerly wind was expected to back to the S. later, the word "later" indicating that the change would not occur in the first part of the period covered by the forecast but in the latter part. The wind was expected to reach gale force in the west and north owing to the intensity of the Atlantic depression and the rapid fall of pressure which was shown by ships' reports to have occurred during the night far out on the Atlantic.

The forecast of weather for eastern districts was "fine to-day, some rain to-morrow," indicating that the renewal of rain associated with the Atlantic depression was expected during the night. As this rain area was not shown on the 7h. map, its time of arrival was a matter of judgment on the part of the forecaster. He would be influenced by the known rapidity of travel of wedges and by the fact that the rain-bearing winds over the Atlantic were of high velocity and would therefore reach the east of the country earlier than might otherwise have been the case. The forecasts for other districts followed on the same lines, rain naturally being forecast earlier over Ireland.

The further outlook, "Unsettled and rather mild," expressed the expectation of the forecaster that the disturbed conditions which had already persisted for many days would continue. These conditions would be associated with a current of air from the Atlantic which in the winter months is nearly always mild.

"EASTERLY" WEATHER.—7h. Thursday, March 8, 1928.

Forecasts for the 24 hours commencing 15h. G.M.T. Thursday, March 8, 1928.

General Inference.

The large anticyclone over Iceland has extended its influence over the British Isles. Winds will be north-easterly and weather mainly cloudy and cold with local showers of rain or sleet, chiefly near the east coast.

Districts	
1. S.E. England 2. E. England	Wind between N. and NE., freshening, becoming strong in places; mainly cloudy, local showers of rain or sleet, chiefly near east coast; cold.
3. E. Midlands 4. W. Midlands	Wind NE., moderate; mainly cloudy; cold.
5. S.W. England 6. South Wales 7. North Wales 8. N.W. England	Wind between E. and NE., mainly moderate; variable amount of cloud; rather cold.
9. N. Midlands 10. N.E. England 11. S.E. Scotland.	Wind N. or NE., moderate or light; mainly cloudy, local showers of rain or sleet; rather cold.
12. S.W. Scotland and Isle of Man 13. (A) W. Scotland	As 5—8.
13. (B) N.W. Scotland 14. Mid-Scotland	Wind NE., light; variable cloud, local sleet showers; rather cold.
15. N.E. Scotland 16. Orkneys and Shetlands	As 9—11.
17. N.W. Ireland 18. N.E. Ireland 19. S E. Ireland 20. S.W. Ireland	As 5—8.

Further Outlook.

Similar conditions.

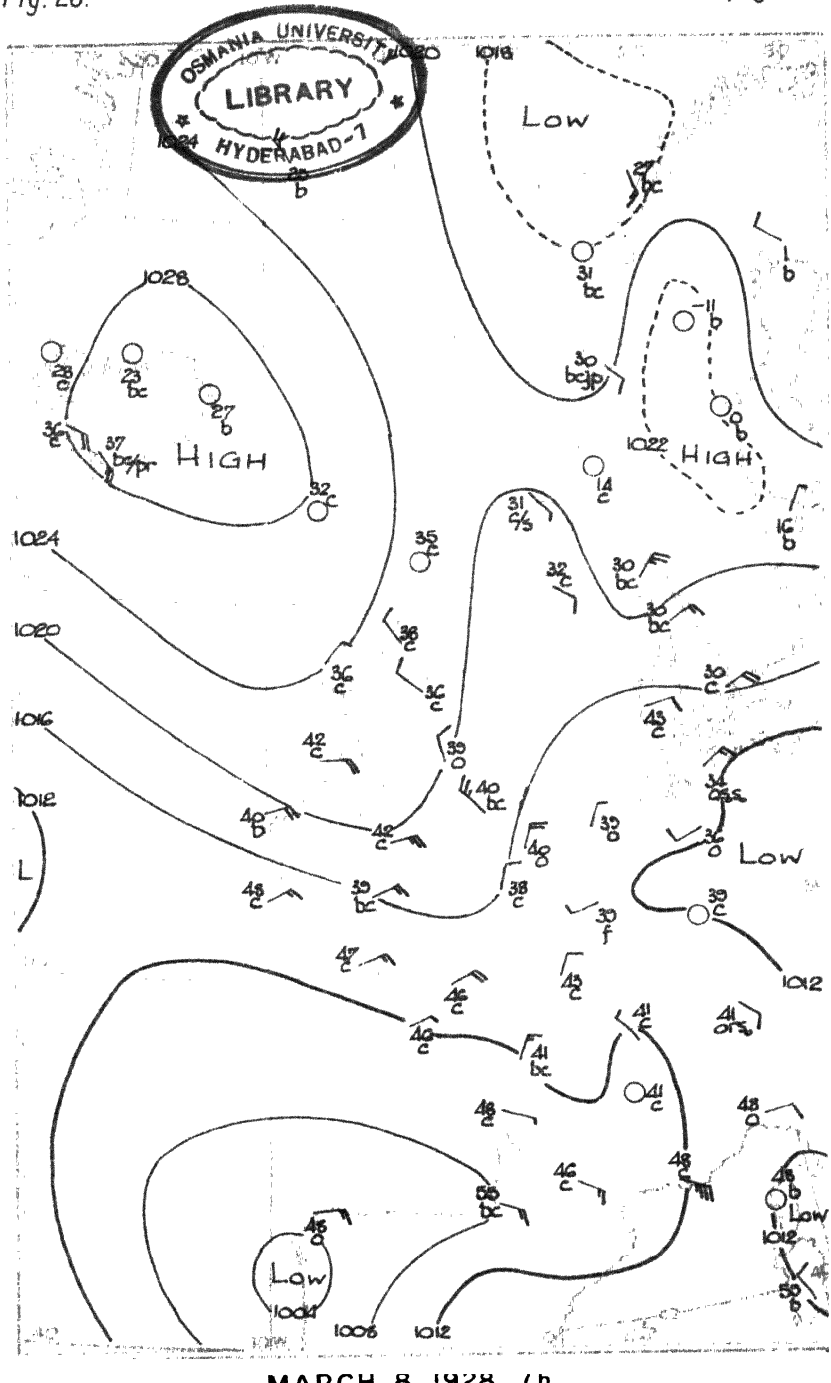
The conditions prevailing at this time with high pressure to the north of the British Isles and over Scandinavia often persist for long periods in the spring, giving cold easterly or north-easterly winds over this country. The low temperature is due to the air having travelled from central Europe or Asia, where at this time of the year the country is still frost bound. Not much precipitation is likely to occur under these conditions unless there should be a considerable development of cyclonic activity over the Bay of Biscay or a secondary depression moves across from the continent in the easterly current when the precipitation may, owing to the low temperature, take the form of snow or sleet. The isobars over the North Sea showed the presence of such a secondary off the Norwegian coast, but the barometric tendencies indicated that this was filling up so that the forecaster felt justified in taking the view that it would not affect our weather. It will be seen from the general inference that mainly cloudy weather was forecast "with local showers of rain or sleet, chiefly near the east coast." The weather on the further side of the North Sea in Denmark and southern Scandinavia was bright, but the air in passing over the relatively warm water would pick up moisture with the result that more cloud would be expected in this country. As the air passes from the sea to the land it tends to be checked by the obstruction to free flow which a land mass always occasions, and this check leads to some piling up of the air in the neighbourhood of the coast and to the tendency to precipitation which, as has been pointed out, is always associated with rising air.

The district forecasts show that while in the eastern parts of the country and the Midlands the sky was expected to be mainly cloudy, in the west a variable amount of cloud was forecast, that is, the sky was expected to clear partially or wholly at times in the west. This was due in part to the greater distance which the air would have travelled from the source of moisture in the North Sea, and in part to the orographic effect by which air in passing over high ground loses some of its moisture in the form of rain on the mountain tops and becomes relatively dry and cloudless when it descends on the lee side of mountains. The weather in those parts of Great Britain which lie to the westward of mountain ranges or high ground, such as the Cornish and Welsh coasts and the western Highlands of Scotland would be expected to feel this influence so that there would be less cloud there than in the eastern parts of the country.

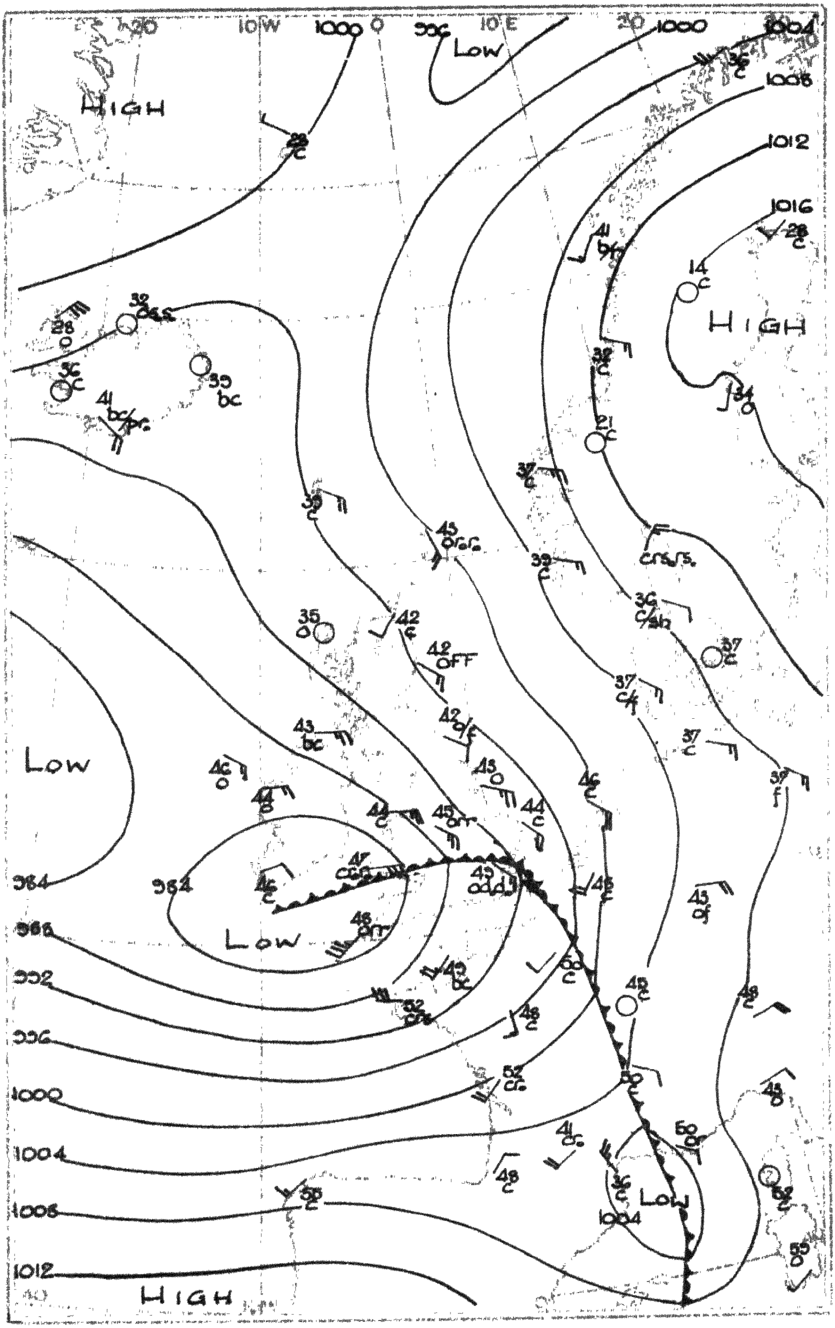
The sunshine records for March 8 showed that this was the case. The Cornish stations, Pembroke and Holyhead in the west of Wales and Stornoway in the Hebrides showed good sunshine records, while many stations in the east had an almost sunless day.

The further outlook "Similar conditions," was based on the forecaster's knowledge that easterly winds tend to persist at this time of year.

Fig. 28. To face page 58.



MARCH 8, 1928, 7h.



MARCH 23, 1928, 7h.

OCCLUDED DEPRESSION FILLING UP.—7h. Friday, March 23, 1928.

Forecasts for the 24 hours commencing 15h. G.M.T
Friday, March 23, 1928.

General Inference.

A deep depression centred north of Scilly is moving slowly north-east and filling up. A rain area now over southern England will move northwards, followed by showers and bright intervals.

Districts.	
1. S.E. England 2. E. England 3. E. Midlands 4. W. Midlands 5. S W. England	Wind SW., fresh or strong at times; showers and bright intervals; rather mild.
6. South Wales 7. North Wales	Wind variable, finally W. to SW., mainly light or moderate; rain at times, bright intervals later; rather mild.
8. N.W. England 9. N. Midlands 10. N.E. England	Wind E. or SE., veering S. or SW. later; mainly moderate; rainy to-day, bright intervals to-morrow but local showers; rather mild.
11. S.E. Scotland	Wind E. to SE., moderate; dull, rain at times; some coastal fog; rather low day temperature.
12. S W. Scotland and Isle of Man	Wind E. to SE., moderate; dull, rain at times; moderate or rather low temperature.
13. (A) W. Scotland (B) N.W. Scotland	Wind E., light or moderate; fair to-day, perhaps local rain to-morrow moderate temperature.
14. Mid Scotland	As 12.
15. N.E. Scotland 16. Orkneys and Shetlands	As 11.
17. N.W. Ireland	Wind easterly to variable, light; variable sky, local showers; rather mild.
18. N.E. Ireland 19. S.E. Ireland	Wind NE. to N., becoming variable, light; rain at times; bright intervals later; moderate temperature.
20. S.W. Ireland	As 17.

Further Outlook.

Unsettled and rather mild.

The pressure at the centre of the depression off the south-west of England was down to 980 mb. and the system was therefore of considerable intensity. With winds of force 6 and 7 on its southern and eastern sides it might well have been expected to give gales in its passage over the British Isles. Examination of the barometric tendencies, however, shows that these were nowhere large, and further that pressure was falling on the northern and north-eastern sides of the depression much more slowly than it was rising on the southern side. This indicated, as has been explained on p. 48, that the depression was filling up as it moved slowly north-eastward, and this information is conveyed in the general inference. The inference goes on to refer to a rain area over southern England which will "move northwards followed by showers and bright intervals." The observations received by the Meteorological Office showed that rain was falling at most English stations south of Birmingham, and the forecaster had to ascertain the cause of this before he could decide upon the probability of its continuance and its line of travel. Temperatures over the English Channel were higher than those over the Midlands and north of England, suggesting that a warm front was situated between these districts. Reference to past weather maps showed, however, that even the relatively warm air which was over the English Channel had probably originated in polar regions and was not truly tropical so that the front must have been a line of occlusion separating two different masses of polar air and not a true warm front. This line of occlusion would travel northwards with the flow of air, and the weather after its passage would be that associated with polar air and not with tropical air, that is it would be showery with bright intervals. This is indicated in the general inference.

A case of this kind where a depression is passing directly over the British Isles generally necessitates much subdivision of the country for forecast purposes as the conditions differ widely in contiguous districts near the centre of a depression. A study of the forecasts of wind for the different districts will indicate the path which the centre was expected to follow. In Wales the forecast was for variable winds becoming W. to SW., as the depression passed over this area and gained a position to the northward of it. In the south of Scotland on the other hand, the wind was expected to remain between E. and SE., that is the centre of the depression would here remain to the southward.

"NORTHERLY" WEATHER.—7h. Monday, May 7, 1928.

Forecasts for the 24 hours commencing 15h. G.M.T. Monday, May 7, 1928.

General Inference.

An anticyclone is centred off the Hebrides and a secondary depression north of the Faeroe Islands will move southward and probably deepen. Winds will be from a northerly point, and weather will be mainly fair at first, but subsequently less settled conditions will spread southward. Temperature will be considerably lower than of late, with ground frost at many places at night.

Districts.	
1. S.E. England 2. E. England 3. E. Midlands 4. W. Midlands	Wind NE., light or moderate, fresh locally, backing NW. later; fine, cooler, with ground frost locally at night.
5. S.W. England 6. South Wales	Wind between N. and NE., light or moderate; fine warm to-day, cooler to-morrow.
7. North Wales 8. N.W. England 9. N. Midlands 10. N.E. England 11. S.E. Scotland 12. S.W. Scotland and Isle of Man 13 (A) W. Scotland	Wind N or NE., backing NW. later, moderate or fresh; mainly fair to-day, becoming less settled to-morrow, cooler, with ground frost at most places at night.
13 (B) N.W. Scotland 14. Mid Scotland 15. N.E. Scotland 16. Orkneys and Shetlands	Wind N., backing temporarily to W., moderate or fresh; becoming cloudy, occasional rain, perhaps some snow to-morrow on the high ground; cold.
17. N.W. Ireland 18. N.E. Ireland	As 7—13A.
19. S.E. Ireland 20. S.W. Ireland	Wind N., moderate or fresh; fair; cooler, with ground frost locally at night.

Further Outlook.

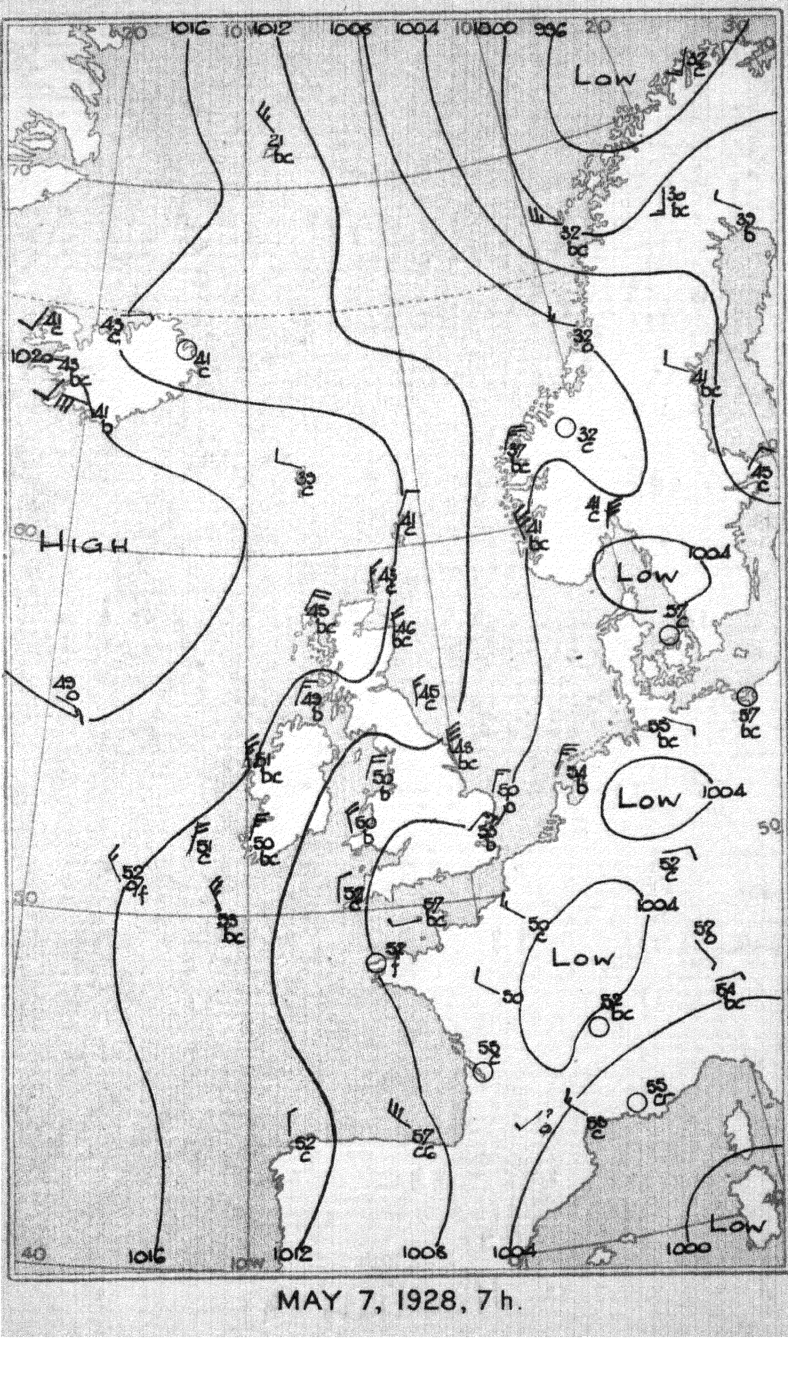
Cold and rather unsettled, with widespread ground frost and some snow on high ground in the north.

On some maps the changes which are taking place are so obvious that the forecaster has no hesitation in taking a certain line, while on others the developments which are likely to affect the weather are only slightly indicated and might easily pass unnoticed if a careful scrutiny of the chart were not made. The present case is an example of the latter type. The changes of pressure over the British Isles and the surrounding areas were everywhere slight, but a westward bulge in the isobars over Iceland suggested to the forecaster a secondary depression which was likely to travel down in the northerly current and pass directly over the British Isles. These indications were strengthened by a slightly falling barometer in the Faeroes between Scotland and Iceland and a wind from NW. there, whereas the wind over Scotland was northerly or north-easterly. No rain was falling at the meteorological stations in Iceland or the Faeroes at the time but if the secondary developed in intensity rain or snow was clearly to be anticipated.

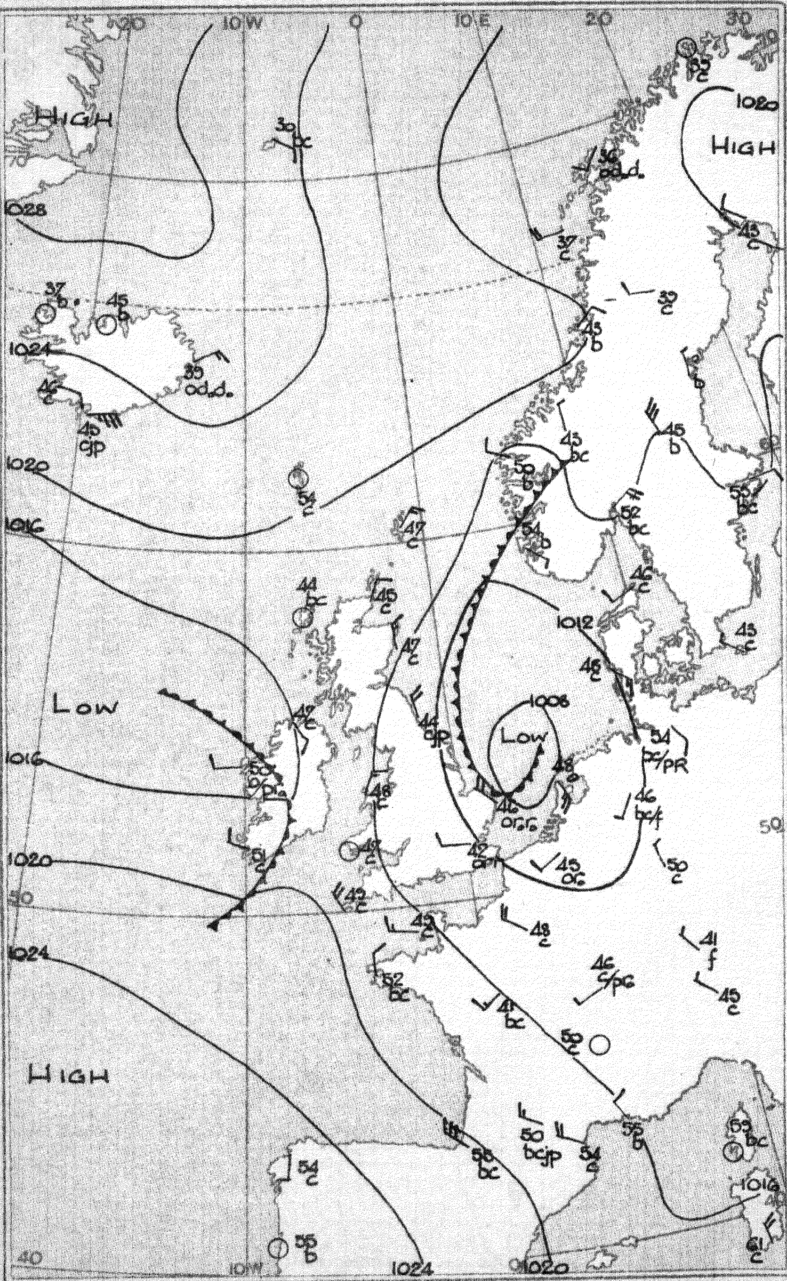
The polar air current over the British Isles might have been expected to give showers in the normal manner of polar currents, but it will be noticed that the forecasts omit any reference to showers in the south of the country and only indicate precipitation in those districts likely to be affected by the northern secondary. This absence of showers from the forecasts was partly due to the fact that there had been an absence of showers in the recent past and partly to the fact that a wedge of high pressure was being formed between England and Iceland which, as it passed southward in front of the secondary, would give fine weather. No report of upper air temperature was available at the time of writing the forecasts, but when one was received shortly afterwards it showed that the air over the south of England was drier than usual and was warmer at great heights than might have been expected. Both these conditions served to render showers improbable.

To return to the effect of the secondary, the forecast for the north of Scotland indicated that the wind would back temporarily from N. to W. and that the weather would become cloudy with occasional rain and perhaps some snow on the following day on high ground. Earlier in the year in similar circumstances snow would have been forecast at sea level also, but in May this becomes improbable and it was only on the mountains that snowfall was to be feared. The fact that the temperature at Jan Mayen, an island in the Greenland sea in the region from which the air current over the British Isles was taking its source, was as low as 21° indicated that it would be unwise to omit all reference to snow from the forecasts.

Fig. 30.



MAY 7, 1928, 7 h.



MAY 23, 1928, 7h.

COL.—7h. Wednesday, May 23, 1928.

**Forecasts for the 24 hours commencing 15h. G.M.T.
Wednesday, May 23, 1928.**

General Inference.

A depression off the Irish coast is moving slowly south-eastward, whilst another persists over the southern North Sea. Unsettled weather will continue with rain or showers in most districts except the extreme north of Scotland, but temperature will be somewhat higher than of late.

Districts.	
1. S.E. England 2. E. England	Moderate northerly or north-easterly winds, fresh at times; cloudy, some rain or showers; temperature moderate.
3. E. Midlands 4. W. Midlands	Moderate north-westerly winds, becoming variable; cloudy, some showers; temperature somewhat higher than of late.
5. S.W. England 6. South Wales	Moderate westerly winds, becoming south-westerly; cloudy, some rain or showers; temperature somewhat higher than of late.
7. North Wales 8. N.W. England 9. N. Midlands	Moderate variable winds; cloudy, some showers; temperature somewhat higher than of late.
10. N.E. England 11. S.E. Scotland	Moderate north-easterly winds, fresh at times; cloudy, some showers; temperature moderate.
12. S.W. Scotland and Isle of Man 13. (A) W. Scotland	As 7—9.
13. (B) N.W. Scotland 14. Mid Scotland 15. N.E. Scotland 16. Orkneys and Shetlands	Moderate north-easterly winds; cloudy, some bright intervals; temperature somewhat higher than of late.
17. N.W. Ireland 18. N.E. Ireland 19. S.E. Ireland 20. S.W. Ireland	Moderate variable winds, cloudy, some rain or showers; temperature somewhat higher than of late.

Further Outlook.

Unsettled.

It was stated in Chapter VI that the weather associated with the pressure distribution known as a col is of an uncertain character, so that when one of these systems appears on the map the forecaster cannot derive much help from his past experience of similar cases, but has to rely on the indications shown on the particular chart with which he is dealing. In the case under consideration, high-pressure systems were situated near Iceland and beyond the Bay of Biscay with depressions westward of Ireland and over the North Sea, the central region of the col being over north Ireland. A comparison with previous charts showed that the principal change in the past 24 hours had been a southward or south-eastward movement of the Atlantic depression. The fall of pressure which was shown at 7h. in the west and south of Ireland suggested that the south-eastward movement would continue. Apart from this, little change in the pressure distribution was anticipated. The view taken is shown by the forecasts of wind for the several districts. In the east of England this was expected to remain of moderate force and blow from the N. or NE., but in the south-west of the country to change from a north-westerly to a south-westerly direction under the influence of the advancing Atlantic depression. The north-west of England was likely to be under the influence of different wind systems at different times near the centre of the col and therefore variable winds were forecast.

Turning to the forecasts of weather no precipitation was expected in the northern parts of Scotland where the dominating influence was the Icelandic anticyclone, but in other districts some rain or showers were anticipated with cloudy skies, in continuance of the weather which was existing at the time. Temperature would in most districts become somewhat higher than of late owing to the fact that the northerly current which had been bringing relatively cold air over the country had been cut off, permitting temperature to rise to a more normal level for the time of year.

Conditions developed in the anticipated manner during the 23rd, but on the following morning a rise of pressure over the country caused the weather to become fairer subsequently than had been expected.

DEPRESSION.—7h. Thursday, June 21, 1928.

Forecasts for the 24 hours commencing 12 noon G.M.T. Thursday, June 21, 1928.

General Inference.

A depression off north-west Ireland is moving north-eastwards. Winds will be S. to SW., and rain will occur generally, though in southern England amounts will not be large.

Districts.	
1. S.E. England 2. E. England 3. E. Midlands 4. W. Midlands 5. S.W. England	Wind SW., moderate or fresh ; cloudy, occasional rain or drizzle ; moderate temperature.
6. South Wales 7. North Wales	Wind SW., moderate to strong ; cloudy, rain at times ; moderate temperature.
8. N.W. England 9. N. Midlands 10. N.E. England 11. S.E. Scotland 12. S.W. Scotland and Isle of Man 13. (A) W. Scotland 13. (B) N.W. Scotland 14. Mid Scotland 15. N.E. Scotland	Wind S., moderate, veering SW., fresh or strong at times ; rainy at first, some improvement later, but occasional rain or showers ; moderate temperature.
16. Orkneys and Shetlands	Wind SE. to S., freshening ; cloudy, some rain ; moderate temperature.
17. N.W. Ireland 18. N.E. Ireland 19. S.E. Ireland 20. S.W. Ireland	Wind SW. to W., fresh or strong at times ; mainly cloudy, occasional rain perhaps brighter intervals later ; moderate temperature.

Further Outlook.

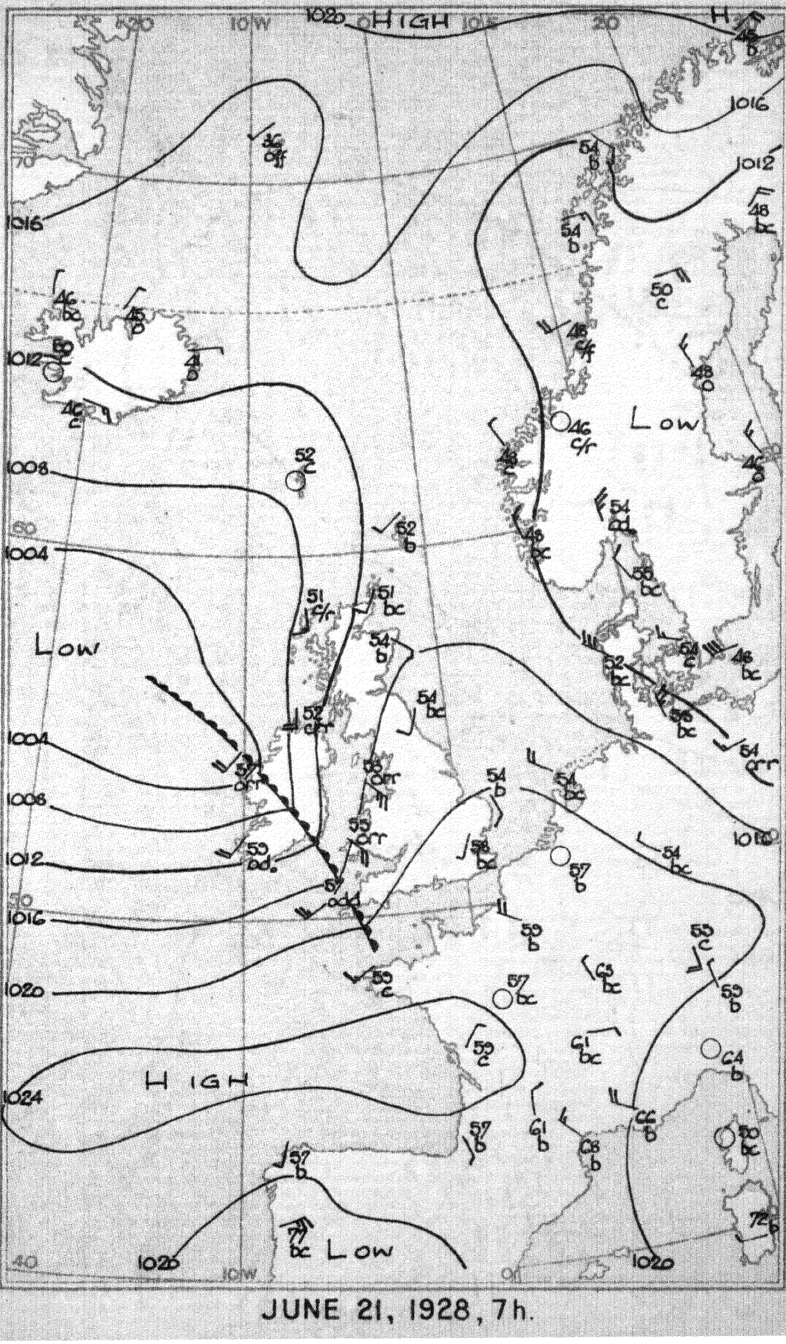
Unsettled.

The depression shown off the Irish coast had moved up from the south-westward during the preceding 12 hours, but the fact that pressure was not falling in the Faeroes directly in front of its path, suggested that its movement was ceasing, though the wording of the general inference indicates that it had not at the time actually ceased. It was not anticipated therefore that the wind would veer much beyond SW. over the British Isles and in the Orkneys and Shetlands the direction was expected to lie between SE. and S.

A striking feature on the map was the belt of rain which covered the west of Scotland, Ireland and Wales and extended in the form of drizzle to Cornwall. The temperature readings were higher in the south-west of Ireland than over Scotland and northern England, thus suggesting a warm front running across central Ireland from north-west to south-east. Some apparent warm fronts prove on closer inspection to be " lines of occlusion " with stale polar air behind them but in the present case the fact that the sky was overcast with a tendency to rain and drizzle in south-west Ireland showed that the phenomenon was of the true warm-front type, having tropical and not polar air behind it. The front would travel in a north-easterly direction with the general air current carrying a belt of rain in front of it. The forecasts indicate this and that after its passage the cloudy weather with occasional rain, which is associated with tropical air, was expected.

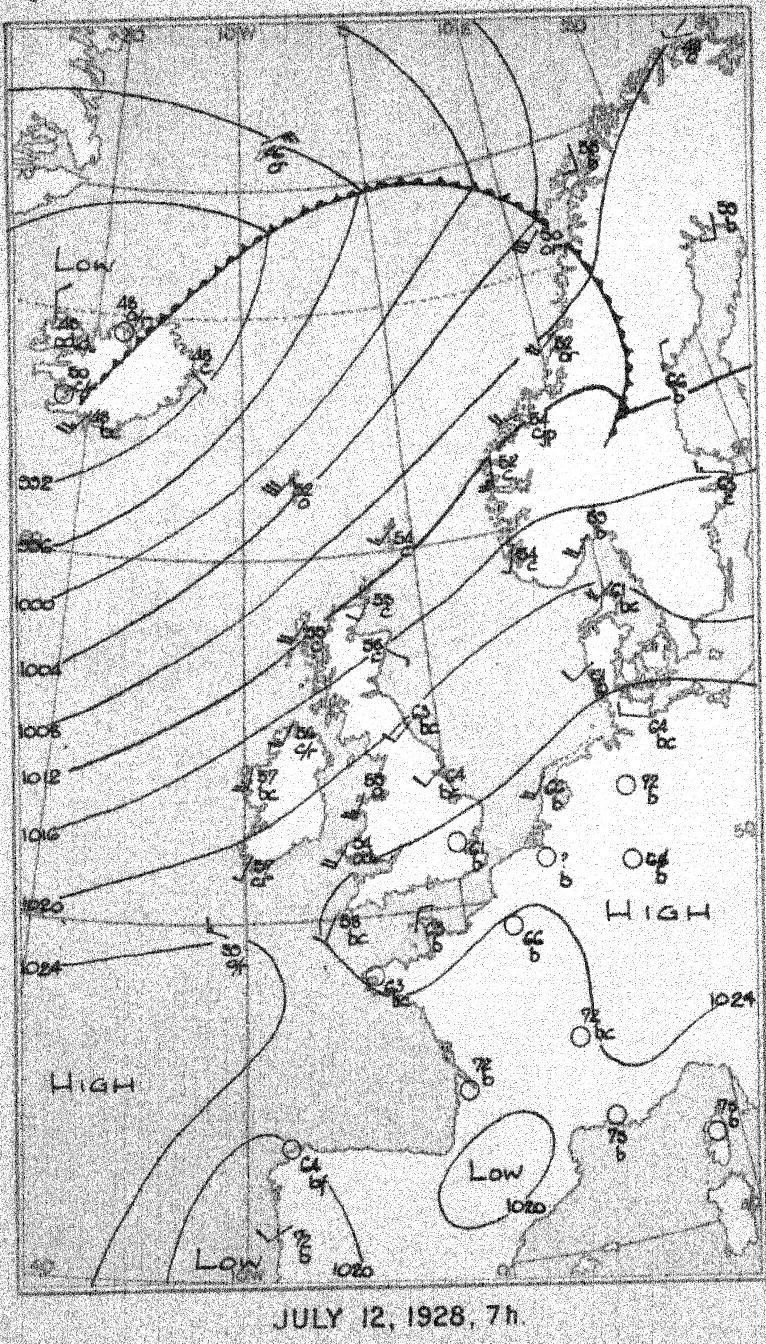
One point in the general inference may be noted, and that is the definite statement that the rainfall in southern England would not be heavy. The temperatures in the south of England showed little contrast on the two sides of the front, readings of about 56° occurring right up the English Channel from the Scilly Isles to the Straits of Dover. This indicated that the front here was not well marked, and confirmation of this is obtained from the small barometric tendencies in the south, the replacement of cold air by warm as a well-marked warm front travels being almost invariably associated with a rapid fall of pressure. A larger fall of pressure existed in the north of Ireland in the present case. There was thus good evidence that the discontinuity shown by the front was much less pronounced in the south of England than in the north, and the rainfall was accordingly not likely to be heavy in the south. The nearness of the anticyclone over France suggested the same conclusion, the proximity of a belt of high pressure acting as a safeguard against heavy rain.

One other consequence of the existence of a warm sector to the depression may be noted. It was pointed out on p. 48 that depressions having a warm sector are still in the stage of growth ; in consequence we find some increase of wind strength allowed for in the forecasts.



JUNE 21, 1928, 7h.

Fig. 33. To face page 63.



JULY 12, 1928, 7h.

FINE SUMMER WEATHER.—7h. Thursday, July 12, 1928.

Forecasts for the 24 hours commencing 12 noon G.M.T. Thursday, July 12, 1928.

General Inference.

A belt of high pressure extends from beyond the Azores across France to central Europe. Over most of England mainly fine and very warm weather will continue, while in the northern and western parts of the British Isles there will be cloudy periods with occasional local drizzle.

Districts.	
1. S.E. England 2. E. England 3. E. Midlands 4. W. Midlands	Light variable or south-westerly winds; mainly sunny and very warm
5. S.W. England 6. South Wales 7. North Wales 8. N.W. England	Light to moderate south-westerly winds: bright and cloudy periods, local drizzle and mist, particularly in coastal districts; moderate temperature or rather warm.
9. N. Midlands 10. N.E. England	As 1—4.
11. S.E. Scotland	Light to moderate south-westerly winds; bright periods, perhaps occasional local showers or drizzle; moderate temperature to rather warm.
12. S.W. Scotland and Isle of Man 13. (A) W. Scotland (B) N.W. Scotland	Moderate south-westerly winds; cloudy periods, occasional local rain or drizzle; some coastal mists; moderate temperature.
14. Mid Scotland 15. N.E. Scotland	As 11.
16. Orkneys and Shetlands 17. N.W. Ireland 18. N.E. Ireland 19. S.E. Ireland 20. S.W. Ireland	As 12—13.

Further Outlook.

Similar.

The general inference stated that "Over most of England mainly fine and very warm weather will continue," while the further outlook is for similar conditions, indicating that a spell of warm fine summer weather is expected. The map shows a depression centred over Iceland with a belt of high pressure stretching from the Azores over the English Channel to Germany. The passage of depressions over Iceland instead of along a more southerly track is generally regarded by forecasters as favourable for good weather in the south of this country, while conversely it is held with even more emphasis that high pressure in Iceland is a bad omen for our weather in the south.

The pressure changes in north-west Europe and over the eastern part of the Atlantic were on this occasion very slight so that there was every reason to think that the anticyclone would continue to dominate the weather over most of England. It was pointed out in Chapter VI that though in the winter months anticyclonic weather is frequently unpleasant, in the summer fine weather is the rule and the forecaster was therefore able to give an optimistic forecast with some confidence. For the south-east of England and the Midlands the forecast of temperature was "very warm." The temperature at the time of the observations, 7 h., was already above 60° at many stations and, with the prospect of an almost cloudless sky, was likely to rise to a high figure in the afternoon.

In the western coastal districts local drizzle and mist were forecast. During the spring and early summer the waters of the Atlantic remain relatively cold, their temperature being generally lower than that of the air, as it takes a long time to heat so vast a mass of water. This condition, sea colder than air, was shown by the readings taken on the s.s. *Homeric* off the south-west of Ireland to exist on the morning of July 12. It is favourable for the formation of sea fog and this would be carried by the light south-westerly wind current on to the western coasts of the British Isles. The same situation earlier in the summer would have led to a forecast of coastal fog. By July conditions become less favourable for fog and mist only was forecast.

A FORECAST OF FIVE DAYS FINE WEATHER.—7h. Tuesday, July 17, 1928.

Forecasts for the 24 hours commencing 12 noon G.M.T. Tuesday, July 17, 1928.

General Inference.

A large anticyclone covers Ireland, England and the southern North Sea. Fine weather will continue over most of the British Isles and probably last all this week in the southern half of the Kingdom. Temperature will tend to rise again.

Districts.	
1. S.E. England 2. E. England 3. E. Midlands 4. W Midlands 5. S.W. England 6. South Wales	Wind NE. to variable, light; bright; becoming warmer again.
7. North Wales 8. N.W. England 9. N. Midlands 10. N.E. England	Wind variable or westerly, light; bright warmer.
11. S.E. Scotland 12. S W. Scotland and Isle of Man	Wind W., light or moderate; fair; rather warm.
13. (A) W. Scotland (B) N.W. Scotland	Wind W. or SW., moderate or fresh; cloudy, local drizzle; moderate temperature.
14. Mid Scotland 15. N.E. Scotland	As 11—12.
16. Orkneys and Shetlands	As 13.
17. N.W. Ireland	As 11—12.
18. N.E. Ireland 19. S.E. Ireland 20. S.W. Ireland	Wind variable, light; fine; warmer.

Further Outlook.

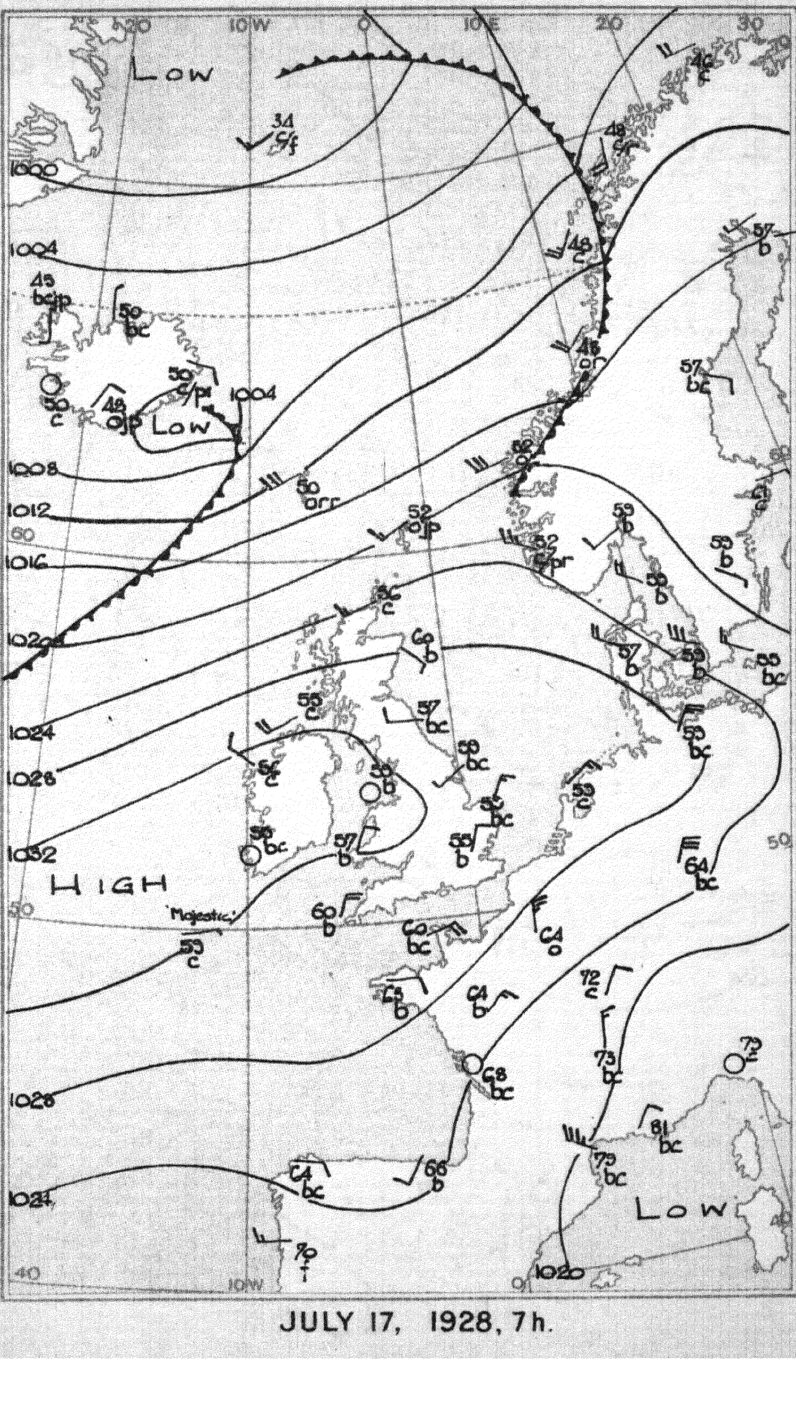
Fine and warm for the rest of this week over the southern half of the British Isles.

It is unusual for the general inference or the further outlook specifically to cover the weather of a period exceeding two or three days in advance, but in the present case the general inference stated that "fine weather will continue over most of the British Isles and probably last all this week in the southern half of the Kingdom." As the inference was issued on a Tuesday morning it thus covered a period of almost five days.

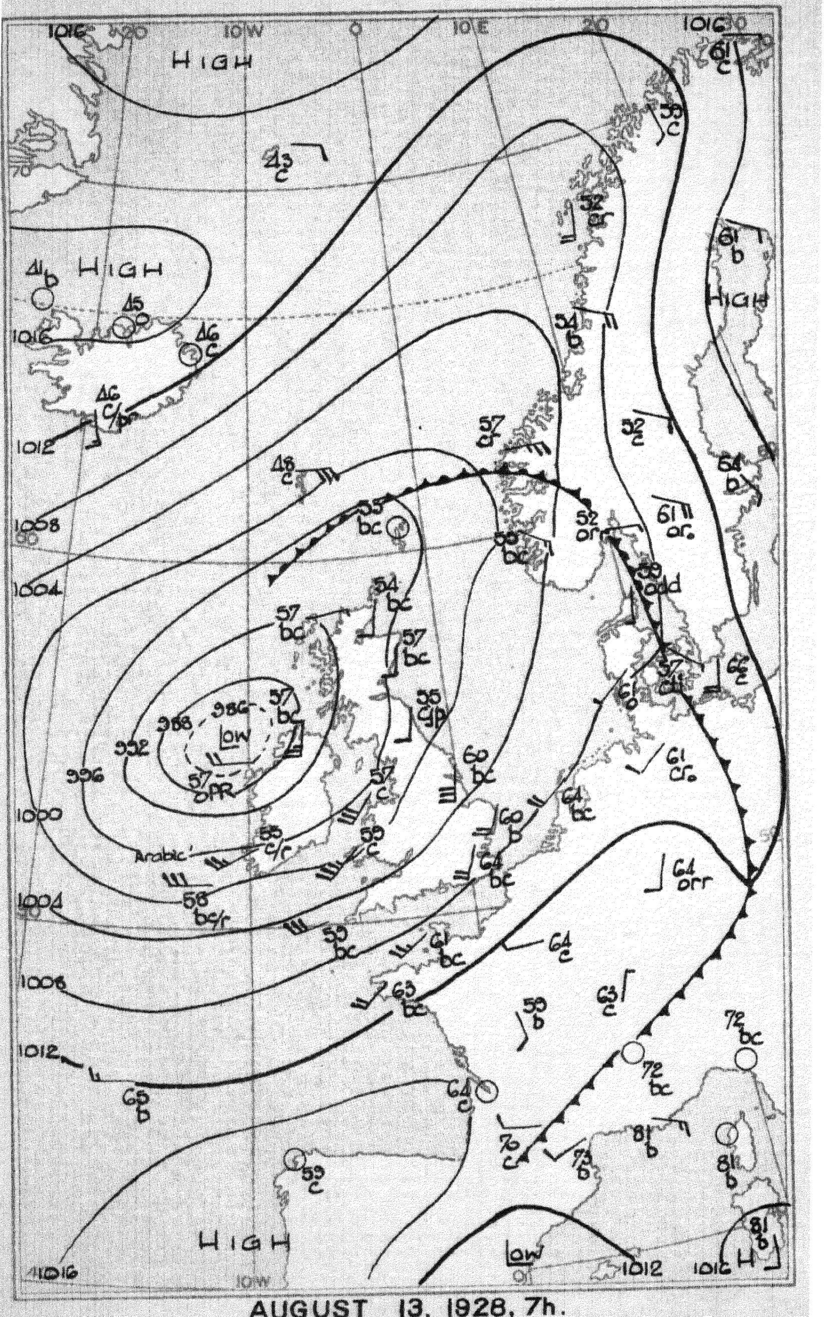
On the occasion of the forecast an elongated anticyclone stretched east and west from the Atlantic across Ireland and England to the southern North Sea. The weather had been anticyclonic for some time in the south of England, thus showing stability in the system, but this alone would not have justified a forecast of continued fine weather for a further five days. Past records show that when in the summer months an anticyclone takes up the position occupied on the morning of July 17, the chances of a continuance of fine weather for nearly a week are good; it was this experience based on similar cases in the past which gave grounds for the issue of the forecast. This proved to be completely justified, no rain being measured at reporting stations in the southern half of the country before the following Sunday, while at many stations the dry spell continued well into the following week.

The present case affords an interesting example of a feature which is often noticed in connexion with forecasts for a period of three or four days, and that is that conditions may develop in such a way that the forecast appears to be going wrong shortly after its issue, though ultimately it will prove to be fully justified. On the evening of July 17 a secondary depression was advancing towards Scotland giving quite definite falls of pressure in the north with cloudy or overcast skies, and it is doubtful whether on this map any forecaster would have had the confidence to issue a forecast of five days' fine weather for the south of the country. The district forecasts issued in the morning show that some development of the kind was expected, moderate or fresh winds from between W. and SW. being forecast in the north and west of Scotland. The secondary as it passed actually led to a freshening of the wind from the westward over a greater part of the country than had been expected, but it did not serve to break the fine-weather spell in the south.

Fig. 34. *To face page 64.*



JULY 17, 1928, 7h.


HIGH
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AUGUST 13, 1928, 7h.

THUNDERY WEATHER.—7h. Monday, August 13, 1928.

**Forecasts for the 24 hours commencing 12 noon G.M.T.
Monday, August 13, 1928.**

General Inference.

A deep depression off north-west Ireland remains stationary. **Weather will be showery with bright intervals and local thunder.**

Districts.	
1. S E England 2. E England 3. E. Midlands 4. W Midlands 5. S W. England 6. South Wales 7. North Wales 8. N.W. England 9. N Midlands 10. N.E. England	Wind SW., fresh or strong at times ; **showers and bright intervals · thunder locally ;** moderate temperature.
11. S E Scotland 12. S.W. Scotland and Isle of Man 13. (A) W Scotland 13. (B) N W. Scotland 14. Mid Scotland 15 N E. Scotland 16 Orkneys and Shetlands	Wind S., moderate or fresh, **showers and bright intervals thunder locally** moderate temperature.
17 N W Ireland 18 N.E Ireland 19. S.E. Ireland 20. S.W. Ireland	As 1—10

Further Outlook.

Showery weather for three or four days.

During the summer months it is always necessary for forecasters to keep a watchful eye for the development of conditions which are likely to lead to thunderstorms. It has been explained that instability in the atmosphere is a necessary condition for thunder and that the most favourable conditions occur when the upper layers of the atmosphere are abnormally cold and the lower layers abnormally warm. A further requisite is a plentiful supply of moisture in the lower layers. There is little on the map for 7h , August 13, to single it out from many others during a cyclonic type of weather, a low-pressure system being shown off the north-west of Ireland with southerly and south-westerly winds over the British Isles. It is only by study of the preceding charts that an unusual feature is found, namely, that the depression had remained stationary for more than 24 hours with a fairly steep pressure gradient on its southern and western sides throughout this period. It is clear that if a depression remains stationary the wind at a little distance above the surface, where it blows parallel to the isobars, will circulate round the centre so that the air which is on the northern side of the depression one morning may be on the southern side the next. This is not true of the normal travelling depression, which is constantly drawing in fresh air in front and throwing out the displaced air at some other point. As the speed of the upper wind can be determined from the distance apart of the isobars in the manner shown in Chapter III, it is easy to calculate how long this circulation would take. Such a calculation demonstrates that the air over the south of England on the morning of August 13 must have been in the neighbourhood of Iceland early the preceding morning. Reference to the weather map for the time shows that the temperature of the air was then between 45° and 50° on the surface. It would be correspondingly cold in the upper layers. Now, in its passage over the Atlantic it would be warmed below by contact with the warm sea water which at this time of the year reaches its maximum temperature, but it would remain cold up above. A moderately unstable condition would thus be attained by the time the air reached the south-west of England and this condition would be accentuated as it passed over land heated by the sun during the day. As the air travelled over the ocean it would also have picked up much moisture, so that both the conditions necessary for thunderstorms, instability and a plentiful supply of moisture, would be fulfilled. Records of upper air temperature taken near Cambridge showed that the conditions postulated were actually experienced. The general inference accordingly after reference to the stationary depression, continues, " Weather will be showery with bright intervals and local thunder." The reports received from observing stations later in the day showed that thunder occurred near Oxford and at Harrogate and Tynemouth, and there can be little doubt that it occurred also at many other places from which reports are not received

FOG AND NIGHT FROST.—7h. Saturday, September 15, 1928.

Forecasts for the 24 hours commencing 12 noon G.M.T. Saturday, September 15, 1928.

General Inference.

Anticyclones are centred over Scandinavia and Ireland Quiet and mainly fair weather will continue with rather high day temperatures and at night slight ground frost locally.

Districts	
1. S E England 2. E. England 3. E. Midlands 4. W Midlands 5. S W. England	Light to moderate variable winds, mainly between N. and E ; bright ; local mist or fog, night and morning rather warm by day, slight ground frost locally at night.
6. South Wales 7. North Wales 8. N W England 9 N. Midlands 10. N E England 11. S E Scotland 12. S.W. Scotland and Isle of Man	Light variable winds ; bright intervals ; mist or fog locally at night and in morning ; rather warm by day, slight ground frost locally at night.
13 { (A) W Scotland (B) N W Scotland	South-westerly winds, light to moderate or fresh ; mainly fair ; moderate temperature to rather warm.
14 Mid Scotland 15. N E Scotland	As 6—12.
16 Orkneys and Shetlands 17. N W Ireland	As 13
18. N E Ireland 19 S E Ireland 20. S W Ireland	As 6—12

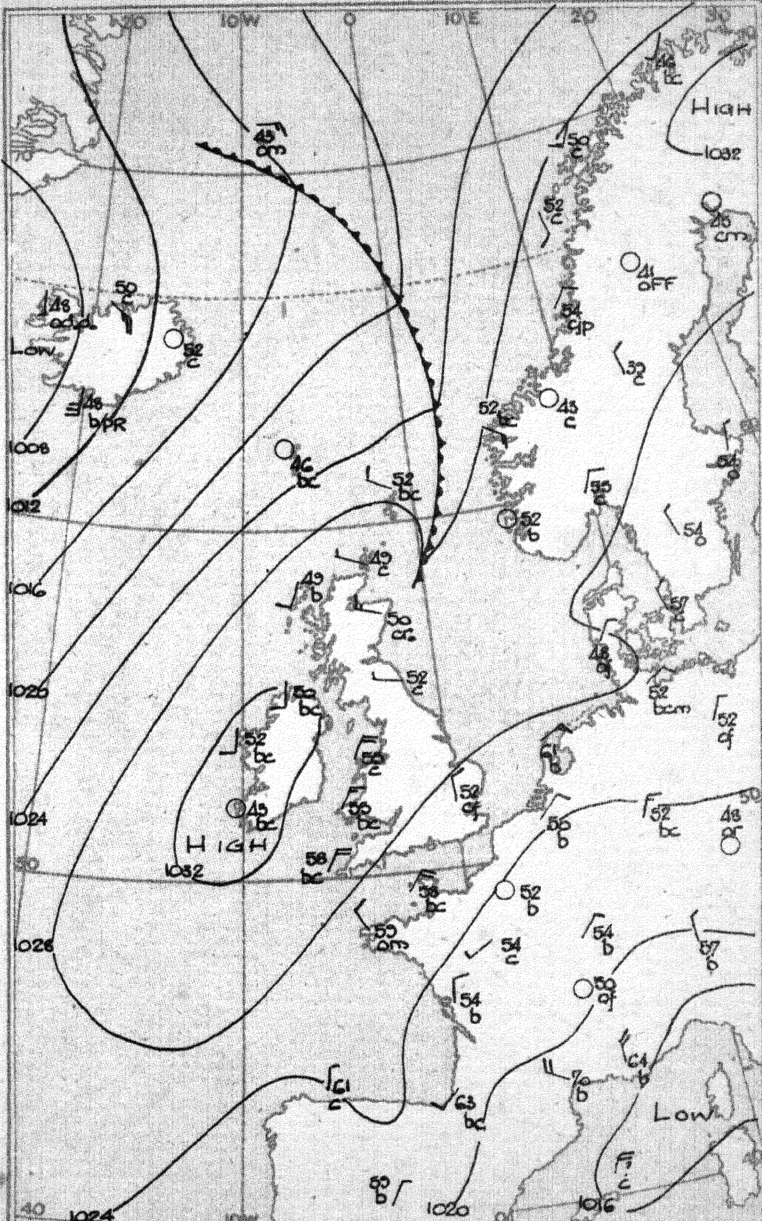
Further Outlook.

No important change is indicated.

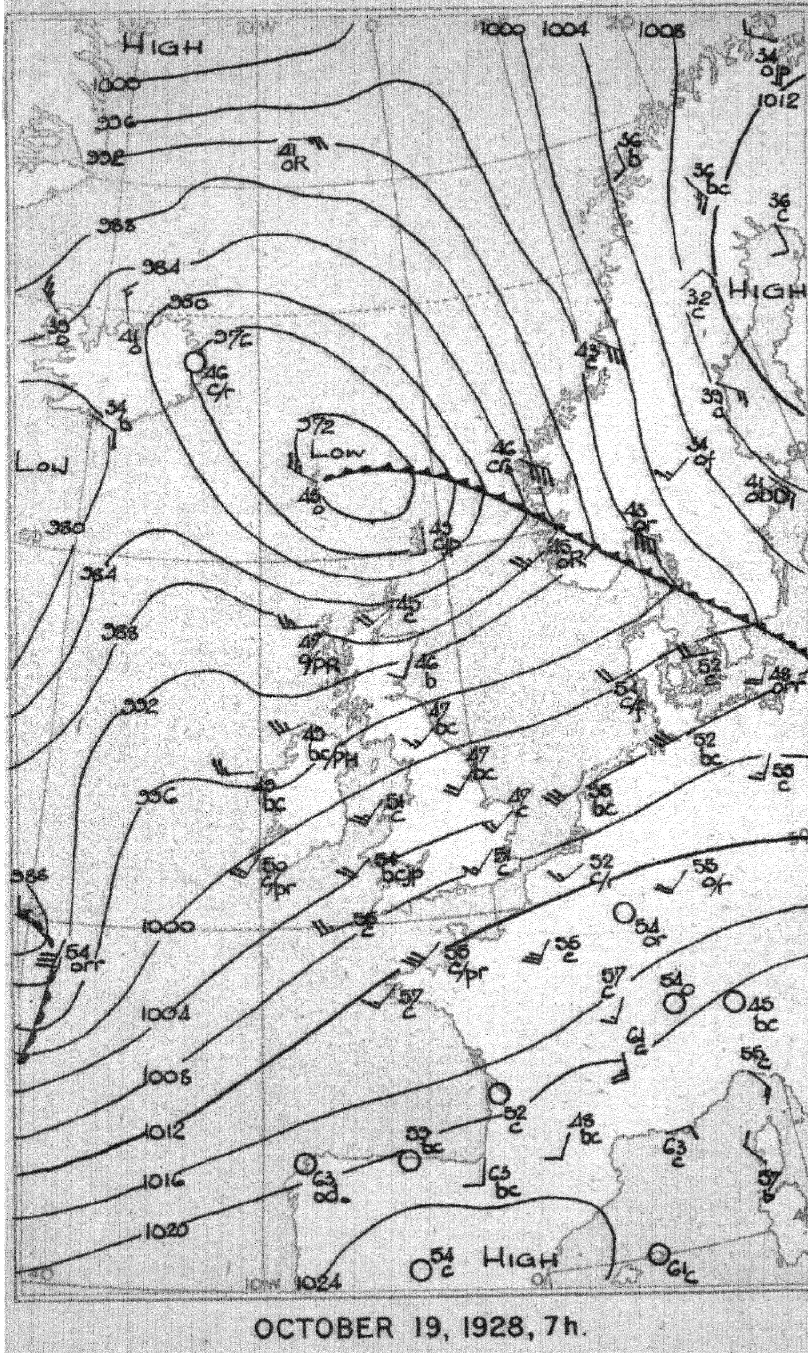
The anticyclone which was centred over Ireland was shown by previous maps to be well established so that the conditions were not difficult for the forecaster. The weather was generally fine over the British Isles, the only stations which reported any rain being on the east coast of Scotland, a region which had just been crossed by a shallow trough of low pressure. The barometer was rising here, indicating clearly that the trough with its associated rain was passing away over the North Sea and would be unlikely to influence further the weather in the British Isles Earlier in the summer there would on this map have been little to forecast other than a continuance of fine weather, but by the middle of September the possibility of fog and night frost cannot be disregarded and the forecaster had to consider whether these were likely to occur, the calm weather and clear skies of an anticyclone being favourable for both. Fog was prevalent at inland stations at the time and though the heat of the sun during the day would be sufficient to clear it there could be little doubt that it would return during the night. Local mist or fog was therefore forecast for the night and the next morning

The temperature at 7 h , though fairly low in central Ireland, 42°, was far from the freezing point in England, being mainly above 50°. By the middle of September, however, there is a period of almost 12 hours between sunset and sunrise and, if the sky is clear, radiation may cause a large fall of temperature during this time, so that with a prospect of a cloudless night a forecast of "slight ground frost locally at night" was issued. This wording should be interpreted to mean that the frost would only occur at places which from their situation are peculiarly liable to night frost, as for example, valley stations.

It will be noticed that the forecast for districts 13 and 16, the west and north-west of Scotland with the northern islands, and that for north-west Ireland, is differentiated from the others by its reference to south-westerly winds, light to moderate or fresh in force and "mainly fair weather" as against "bright weather" in other districts. A well-marked trough of low pressure was shown by ships' reports to exist on the Atlantic ; it was the anticipated movement of this to the east or north-east which led the forecaster to expect moderate or fresh south-westerly winds, and to hint at the possibility of some rain before the end of the period by use of the adverb "mainly" before the word "fair." The effects of this trough were clearly shown by 7h the following morning when moderate or fresh southerly winds were reported from stations in the north-west, the region of highest pressure being displaced from Ireland to England. This displacement of an anticyclone by an advancing trough of low pressure is typical although the displacement is frequently only temporary, the anticyclone recovering itself as soon as the trough has passed on its way.



SEPTEMBER 15, 1928, 7h.



OCTOBER 19, 1928, 7h.

DEPRESSION ON ATLANTIC.—7h. Friday, October 19, 1928.

Forecasts for the 24 hours commencing 12 noon G.M.T. Friday, October 19, 1928.

General Inference.

A further depression off western Ireland is likely to move rapidly eastwards and cause mild unsettled conditions to spread from the west bringing further rain and freshening winds from a southerly point to all districts.

Districts.	
1. S.E. England 2. E. England 3. E. Midlands	Fresh south-westerly winds, becoming strong southerly; cloudy at first then rain; mild.
4. W. Midlands 5. S.W. England 6. South Wales 7. North Wales 8. N.W. England	Fresh south-westerly winds, becoming strong southerly and reaching gale force at times in exposed places cloudy, some rain; mild.
9. N. Midlands 10. N.E. England 11. S.E. Scotland	As 1—3.
12 S.W. Scotland and Isle of Man 13. (A) W. Scotland (B) N.W. Scotland 14. Mid Scotland	As 4—8.
15. N.E. Scotland 16. Orkneys and Shetlands	As 1—3.
17. N W. Ireland 18. N.E. Ireland 19. S.E. Ireland 20. S.W. Ireland	Strong southerly winds reaching gale force at times in exposed places, veering to-morrow; rainy at first, showers and bright intervals later; mild to-day, cooler to-morrow.

Further Outlook.

Showers with bright intervals; temperature becoming lower.

The general inference indicates that a fresh depression over the Atlantic is likely to dominate the situation during the period of 24 hours from noon.

It would be difficult to find a better example than this of the value of ships' observations in forecasting. Readings from the Atlantic liners *Majestic* and *Carmania* had shown that in the area 750 miles west of Land's End pressure had fallen about 25 mb. during the preceding night Occurring in a period of about 12 hours, it was a fall of unusual magnitude for the latitude of the British Isles. It indicated that an intense depression was developing rapidly over the Atlantic. Over the British Isles at the time the weather was for the most part fine though showers were falling at a few places The presence of a complete canopy of low cloud at Valentia, associated with a slowly falling barometer in the south-west of Ireland and of much high cloud of the cirrostratus and altostratus types further east, form the only indication of the depression given by land observations.

For the forecasts the eastern districts of England and Scotland were grouped together and over this area the wind was expected to become strong from the S. with rain developing after cloudy weather. In the western parts of England and Scotland the wind was to reach gale force in exposed places, and it will be noticed that the weather predicted was "cloudy, some rain," indicating that the rain might occur at any time during the 24 hours from noon and would not be confined to the later part of the period as in the east.

In judging the time when the rain would commence the forecaster had to take into account both the position of the rain area at the time as shown by ships' reports from the Atlantic and the speed at which the upper winds were likely to bring the rain-bearing air over the British Isles. He was helped by an observation of the movement of high cloud over Liverpool which showed a rapid current of air from the WSW. at the cirrus level, indicating that the rain area was likely to spread eastward rapidly and to reach the west of England by midday.

The forecast for Ireland showed further important differences. Here the wind was expected to veer "to-morrow" and rainy weather at first, to be followed by showers and bright intervals later with cooler weather. This shows that the trough line of the depression was expected to pass over Ireland during the period of the forecast, and to be followed by the bright but showery weather of the polar air in its rear.

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